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ART. XXII.—*On a new Process for the Electrical Deposition of Metals, and for constructing Metal-covered Glass Specula;* by Professor ARTHUR W. WRIGHT, Yale College.

IN a paper by the writer, published in this Journal, January, 1877, an account was given of a method of producing metallic films upon the inner surface of exhausted glass tubes, by the action of a succession of energetic electrical discharges. The thickness of these films could be varied, from a tenuity such that the coating barely gave indications of a metallic luster, and scarcely dimmed the intensity of transmitted light, to the point where perfect opacity was attained, by simply continuing the action of the current for a shorter or longer time. They were produced by forming the negative electrode of the metal to be deposited, exhausting the tube, and passing through it the current from an induction coil. The metallic coatings thus obtained, as seen from the exterior, were very brilliant, but the condition of the inner surface was not readily observed, and the nature of the process made it seem probable that they possessed a dull or even a frosted surface. With a view to obtain the films in a form better suited for examination, a modification of the apparatus was contrived, by which they could be deposited upon pieces of plane glass. At first this object was attained by inserting narrow slips of glass into the tube by the side of the electrode, in the manner suggested in my former paper, and very good results were gained. But, as the nearer portion of the plate received a larger share of the metal, the thickness of the deposit was not uniform, and it

was found necessary to construct a special apparatus, in which the relative positions of the plate and the electrode could be varied, so as to give the latter an equal action upon all parts of the surface to be covered. The plan employed was as described in the following paragraphs.

A rather thick-walled glass globe about seven centimeters in diameter, blown upon the end of a tube twenty-five centimeters long and fifteen millimeters in diameter, was used to form the receiver. The top of the globe opposite the tube was cut off, so as to form an opening forty millimeters in diameter, and the edge ground flat, in a plane perpendicular to the axis of the tube. The end of the latter was drawn somewhat smaller in a gas-flame, and a glass stop-cock attached to it with cement. A little way above this, a platinum wire was fused into the glass to serve as the positive electrode. The cover of the vessel was made by cutting from a similar globe a portion corresponding in size to the part removed, but with the neck attached, the two pieces being carefully ground so as to fit closely. When they were placed together, a little cement applied to the outside along the line of juncture rendered the joint perfectly air-tight. The tube or neck of the cover was five centimeters long, and was also somewhat reduced at the extremity by drawing it smaller. Into this was cemented a small and thick-walled tube extending to a point near the center of the globe. A platinum wire was placed in this tube, and was fused in at the top, enough being left projecting to form a small loop for the attachment of the wire from the coil. The inner end of the wire terminated at about one centimeter from the lower end of the glass tube. Into the latter was slipped a wire of the metal to be deposited, which, in all cases, was the negative electrode,—the part within the tube being long enough to make good contact with the platinum wire, and being bent somewhat so as to cause it to retain its place by friction. In some of the experiments a different cover was used, made from a glass funnel, the neck of which was left somewhat longer to afford more room for the swinging electrode, as described below, and the tube carrying the latter was fitted into the top by grinding so as to make an air-tight joint.

For the support of the plate, a small watch-glass, about three centimeters in diameter, was employed, to one edge of which a thread of glass was fused by a blow-pipe flame, and then bent so as to form a loop by which it could be suspended like the pan of a balance. A small hook of glass was also attached to the side of the thick tube carrying the electrode, and upon this the pan was hung, the loop being so formed as to allow it to swing freely in all directions. The pan, when in place, was about fifteen millimeters below the end of the tube

from which the electrode projected, the latter being adjusted to the proper distance by sliding it up or down in its support as occasion required. By slightly inclining the globe the extremity of the wire could thus be readily brought over any point of the plate. In some of the experiments the plate was stationary, being held in a little tripod of glass threads, or simply laid upon the bottom of the globe. In these cases the tube holding the electrode was jointed near the top, the two portions being connected by a hook and loop of platinum or magnesium wire. It could thus be made to traverse all parts of the plate by giving suitable movements to the globe.

When adjusted and closed the receiver was attached to the Sprengel pump. By means of a small air-pump of the ordinary construction, connected with this by a stop-cock and flexible tube, the whole apparatus was exhausted as far as possible and then dry hydrogen admitted, this being repeated two or three times in order to remove the air and moisture. The process of exhaustion was then completed with the mercury pump. The degree of rarefaction required varied somewhat with the metal to be deposited, but was rarely above 2·5 millimeters. For platinum the best results were obtained, when it was from 1·5 to 1·75 millimeters. The use of hydrogen is not in all cases necessary, as some of the metals can be deposited perfectly well with only air in the receiver. This is especially the case with gold, but platinum, although ordinarily not easily combined with oxygen, becomes tarnished with a film of what apparently is the blue oxide, unless the air is removed. The electrode itself was formed of a small wire, usually not more than one-fourth of a millimeter in thickness, bent at the end into a circle three or four millimeters in diameter, the plane of which was perpendicular to the straight portion of the wire entering the glass tube, and parallel with the surface of the glass plate situated beneath it. Its distance from the latter was generally about three millimeters, though considerable variations were possible. When it is farther away the process of deposition goes on much more slowly, though the results are in most cases quite as good as when it is nearer. After the process of exhaustion was completed, the stopcock was closed, and the apparatus removed from the pump, for greater convenience of manipulation in applying the current.

The electrical apparatus employed consisted of an induction-coil capable of giving sparks four or five centimeters in length, and a battery, the power of which could be varied according to circumstances. It consisted usually of pint Grove cells, from three to six in number, not completely filled, or charged with rather weak acid, and a plunge battery of five cells, of which one, two, or more were used, as occasion required, the whole being

joined in a continuous circuit. By immersing the plates of the plunge battery more or less, as well as by varying the number in the circuit, the strength of the current could readily be changed within the limits desired. The various metals required currents of different strength, and the power best suited to each had to be determined by trial. It was found advisable in most cases to regulate it so that the temperature of the electrode was below that of a red heat, or such as barely to redden it. Of course with the more fusible metals it was necessarily much lower than this. The metal is actually volatilized by the discharge, as is shown by the fact that the characteristic lines of its spectrum may be seen with a spectroscope, and the film is formed by the condensation of its vapor upon the cooler glass surface. For the production of films with brilliant surfaces, the strength of the current must not be great enough to give the discharge a disruptive character, as this separates some of the metal in the form of powder.

The primary object of the experiments was to obtain films of the different metals upon thin pieces of flat glass for the purpose of investigating some of their optical characters. The apparatus proved to be perfectly successful in its operation, and beautiful films of gold, silver, platinum, and bismuth, were obtained with ease and certainty. As has been mentioned, it seemed probable that the surface of deposit would be dull, but the first trial showed that this anticipation was incorrect, and the films when removed from the receiver exhibited surfaces of exquisite perfection and the most brilliant polish. They can only be compared to the surface of clean liquid mercury, far surpassing in luster anything that can be obtained by the ordinary methods of polishing.

This circumstance suggested at once a valuable application of the process in the production of specula for optical purposes, and the subsequent investigations were directed to this end. The mirrors first made had been formed upon disks of thin glass, such as are commonly used as covers for microscopical objects, those being selected which were most free from defects, and had the best surfaces. By means of a very delicate assay balance, the weight of the glass disks, both before and after receiving the deposit, could be obtained to the one hundredth part of a milligram, and hence it was easy to calculate the thickness of the metallic layer in any instance. By this means the relative transparency of the different metals can be determined, and the relation between the amount of light transmitted and the thickness of metal traversed by it. The more particular consideration of these and some other matters of interest as bearing upon the optical characteristics of the metals is deferred to another time, and it is only necessary to men-

tion here the results of some measurements which were made in order to determine the limiting thickness of a film in regard to the transmission of light, that is, the thickness of a film which would allow only an inconsiderable proportion of the incident rays to pass through. As the metallic luster is developed gradually with the increasing amount of metal, showing conclusively that light actually penetrates these substances to a certain depth, it was important to ascertain whether the thickness of the layer, sufficient for a virtually complete reflection of light, would be great enough to affect perceptibly the figure of a mirror of glass upon which it was laid down.

Experiments for this purpose were made with gold and platinum, and the process of deposition was continued until the films appeared to have just reached the condition of complete opacity. On removing them from the receiver, however, it was found in both cases that a very small amount of light was still transmitted, as, on holding them close to the eye, a brilliant object, like the sun or a bright flame, could be seen through them. The thickness of the gold layer was found to be 0·000183 mm., that of the platinum 0·000174 mm., or approximately one-fourth the length of a wave of light at the red end of the spectrum. The gold, although thicker than the platinum, transmits perceptibly more light, showing that it is the more transparent of the two metals. As the films employed for mirrors may be much thinner than the amount mentioned without an appreciable diminution of the intensity of reflected light, it is evident that the figure of a perfectly wrought glass mirror will not be changed, when the metal is uniformly deposited, to such an extent as to affect its performance unfavorably. A platinum film of one-fifth the thickness of the one described forms a brilliant mirror, transmitting but a very small percentage of light. The perfect control of the process obtained by the use of the movable electrode will even make it possible to apply the method of local correction for the improvement of a defective figure, or to parabolize a spherical mirror by depositing the metal in a layer increasing in thickness toward the center, though, of course, it would be better to avoid a somewhat tedious operation by securing the perfect form of the glass beforehand.

Of the metals that are suitable for the formation of specula, platinum appears to be the most valuable. For while, when well polished, it is but little inferior to silver in reflecting power and freedom from color, it does not become tarnished by oxidation or the action of sulphurous gases, and when dulled by atmospheric deposits the surface can be cleaned by washing with water or with acids, which is an important advantage. By the method here described it can be deposited upon glass

surfaces very easily, and a mirror of the most perfect surface produced at once, without the necessity of a single touch to complete it. Several such mirrors have been made in the course of these experiments, by the use of concave glass lenses, with the most satisfactory results. The metal film adheres strongly to the glass, and when of sufficient thickness appears to be very firm and hard. In mirrors silvered by the ordinary method, trouble is often experienced from the insinuation of moisture between the glass and the metal, resulting finally in the separation of the latter. In those prepared by the new process the adherence of the film is so close as to render such an effect impossible. As a test of this, a small silvered speculum was placed in a beaker of water where it remained for two weeks, and besides this was wetted and dried repeatedly, without showing the slightest tendency to suffer the penetration of the moisture. Similar results were also obtained with platinum and gold films.

With silver the process likewise succeeds well, but it is more difficult to obtain good surfaces than with gold or platinum. The metal is volatilized with extreme ease by the action of the current, and the energy of the discharges must not be too great. Of several trials made with this metal the most successful was one in which not only the degree of exhaustion of the receiver was less than had been employed in other cases, being only to three millimeters, but the electrode was more distant from the plate, and the battery weaker. The action proceeded slowly in this instance, but with the result of producing an excellent film. With a stronger current the deposit is rapidly made, and has a fine luster, but the surface has a yellowish color. This is perhaps partially due to a slight degree of oxidation, but also appears to be owing in part to the deposition of a portion of the metal in the form of fine powder, the vapor of the silver as it streams from the electrode toward the more distant portions of the plate becoming partially condensed, and falling on it in minute particles. That such a result would follow from this cause was shown by some of the experiments in which a rather strong battery was employed. The whole interior surface of the globe was in a short time covered with the powdered metal, appearing an intense purple where thinnest, and shading gradually to deep blue where thickest, the color being the same by both transmitted and reflected light. The metallic luster was wanting, though it was readily developed when a portion of the powdery coating, which was easily removed, was rubbed against the surface of the glass with some pressure. The defect was, to a considerable extent, remedied by surrounding the electrode with a small glass tube projecting some three millimeters beyond it, so as to clear the surface of

the plate by an interval of only one or two millimeters. This had the effect to cut off the lateral portion of the discharge, and to confine its action to a limited area immediately below the extremity of the wire.

The yellow tarnish is removed with the greatest ease by gently rubbing the surface with soft chamois leather and a little rouge, and the metal is so hard, that, when this operation is performed with care, the polish is not at all, or but very slightly, affected. Even then, however, the metal is not perfectly white, having still a very faint yellow tinge. It is well known that silver is not a perfectly white metal, for light which has undergone repeated reflections from polished surfaces of this metal appears yellow or reddish-yellow, though this color is not perceptible when the light has undergone but a single reflection. But the real cause of the yellowish tint may possibly be found in the very tenuity of the films, which when prepared in this way have a beautiful and intense blue color by transmitted light. When not too thick, the amount of blue rays which they suffer to pass, may be sufficient to cause, by their abstraction, a perceptible tinge of yellow, the complimentary color, in the reflected rays. If this were really the case, the coloration should grow weaker with an increase of thickness, and disappear when opacity is reached. Some of the results obtained seem to favor this view, and the probability of its correctness is strengthened by the facts related in the next paragraph, but further experiments are needed to decide the question satisfactorily.

One result of the investigation has been to show that the color of the light which has passed through a layer of metal varies somewhat with the thickness of the film. This was known to be the case with gold, and experiment has shown it to be true of platinum and bismuth also. Thus the latter in a very thin film appears a clear bluish-gray, while a much thicker film appears brownish. Platinum in a thin layer has a grayish tint, which varies, as the film is made thicker, to a peculiar brownish shade, somewhat like that of sepia, passing into brownish yellow, and finally becoming a deep yellow, even inclining somewhat to orange, in the thickest films obtained. Now this color is almost exactly complimentary to that transmitted by silver, and the possibility suggested itself of making a mirror which should be perfectly white by reflected light, by depositing first a thin stratum of silver and over this another of platinum, the relative thickness of the two being properly regulated by observing the color of the transmitted light. An experiment made with a circular disk of flat glass was perfectly successful, the platinum being readily deposited upon the silver, the yellowish tint of which it entirely removed, producing

a white and brilliant reflecting surface. By transmitted light the film, as it was anticipated would be the case, has a pure neutral tint, with no perceptible color of any kind.

The value of such a combination for specula is evident, for though until careful measurements are made, it cannot be asserted that the absolute reflecting power is increased, the whiteness of the layer, and the protection afforded by having the surface covered with an unalterable metal, are very substantial advantages. In constructing large mirrors it will probably also be found to result in a material saving of time, the silver being so much more rapidly and easily deposited than the platinum. The process can also be used with great advantage for the construction of solar eye-pieces for telescopes, since the compound film can be deposited directly upon the surface of the lens, and made thick enough to reduce the intensity of the light as much as may be desired. An image, nearly or quite colorless could thus be obtained, and the disturbance of the rays should be less than that produced by the interposition of a dark glass of the ordinary kind.

As has been mentioned, some experiments were made with bismuth, and a mirror of excellent surface was obtained, but the metal is inferior to platinum in brilliancy, and has a decided color. The great facility with which films are obtained with it might recommend its use for mirrors in some cases, but for most purposes other metals are to be preferred. Attempts to produce mirrors of iron and nickel were but partially successful, as it was difficult to prevent tarnishing by oxidation. Some good iron films were obtained, however, which were very brilliant. They were exceedingly hard, and adhered to the glass with such tenacity that at first it seemed as if they had been fused into it. But when the film was dissolved off by an acid the glass was found not to have been acted upon at all. A singular characteristic of the iron in this condition is its chemical inertness. Films prepared more than six months ago and freely exposed to the air, which for a part of the time too, was excessively charged with moisture, have not shown the least alteration. Nitric acid placed upon one of them for a short time produced scarcely any effect, and nitro-hydrochloric acid acted upon it with about the same readiness as it does upon platinum. This may be due to the extreme thinness of the film, in consequence of which, even the exterior atoms of the iron, being within the range of the molecular action of the glass, are held by a force tending to oppose and neutralize the attraction of reagents that ordinarily attack the metal energetically.

It is not at all necessary that the object upon which the metal is deposited should be of non-conducting material. This is shown by the fact that the process continues to go on after

the glass has become covered with a perfectly continuous layer of metal of considerable thickness. The success of the experiment of covering a silvered glass with platinum is additional evidence of the same fact. In order more fully to test the question whether a deposit could be made upon a solid piece of metal, a small silver coin was placed in the pan under an electrode of gold. It was covered in a few minutes with a beautiful coating of the latter metal, which was found to be very hard and to adhere perfectly, having also, in every respect, its proper color and luster. At the beginning of the process, while still thin enough to allow light reflected from the silver to pass, it had a greenish color, producing a curious effect.

As an example of the applicability of the process to practical purposes, it may be of interest to mention the results of some experiments in the construction of a small Gregorian telescope, the specula of which were covered with platinum by the method described, and with entire success. The larger mirror has a diameter of a little less than four centimeters, and both this and the smaller one, so far as the nature of the surface is concerned, appear absolutely faultless. As only common lenses were employed in its construction the performance of the instrument is not remarkable, but it is sufficiently good to warrant the assurance that the method will be serviceable for the production of specula of exquisite quality for optical purposes. The size of the apparatus, which, for convenience in experimenting, was necessarily small, did not permit the introduction of larger mirrors than this, but there seems to be no reason for doubting that much larger specula can be successfully made in this way. The amount of time required for obtaining the platinum covering of this mirror was about three hours, during which the coil was kept in continuous action, with a battery power equivalent to four or five small Grove cells. Mirrors of larger size would of course require a longer time, but with suitable apparatus a much stronger battery and larger coil could be used, which would materially accelerate the operation. A plate two centimeters in diameter can be covered with platinum in twenty or thirty minutes sufficiently thick to form a good speculum. For gold or silver the time would not be more than from ten to fifteen minutes.

Many useful applications of this process may be found, and its use is not limited to those metals which have been mentioned here. Moreover for many of them no other available process is known by which they can be deposited in a uniform layer and with a brilliant reflecting surface upon glass. A very thin layer of platinum, or still better of silver and platinum together, could be used with great advantage in the *camera lucida* and similar instruments. Very perfect mirrors for gal-

vanometer needles, and for delicate torsion apparatus, can be expeditiously formed in this way, and by the use of very thin glass, or the most delicate films of mica, they may be made of almost inappreciable weight. For the mirrors of heliostats, and other reflecting instruments in which a metallic surface is necessary, the specula produced by this method will be especially valuable. For telescopes, the beautiful process of Liebig and Foucault, for forming silvered glass specula, is recommended by the ease with which it is applied, and the rapidity of its operation. But the perishable nature of the delicate silver film, and the difficulty of securing a firm and permanent adherence, are serious disadvantages. These are entirely avoided by the use of an unalterable metal like platinum; and though for instruments of the largest size the process here described may be found impracticable, for those of more moderate dimensions there is every reason for believing it may be employed with complete success. The labor and time required for its application are indeed drawbacks; but there is compensation for this in the important circumstance that the mirror comes out of the receiver with a surface of inimitable perfection, which would in fact only be injured by any of the ordinary methods of polishing.

Yale College, August 8, 1877.

ART. XXIII.—*A new and ready method for the Estimation of Nickel in Pyrrhotites and Mattes;* by MARGARET S. CHENEY, and ELLEN SWALLOW RICHARDS.

WE had occasion several months since, to make a number of determinations of nickel in mattes where, for commercial reasons, the element of time was of considerable importance. Our attention was thus called to the various processes which have been recommended for the separation of nickel from iron, and we have submitted these processes to comparative tests, but no one of them seemed perfectly satisfactory for our purpose.

The method most commonly used, perhaps, depends upon the separation of iron as a basic acetate. (Fresenius, page 363.) This method requires considerable analytical skill and practice in its use. The large dilution and subsequent evaporation necessary render the operation a tedious one, even without the repeated re-precipitations which are indispensable to a complete separation.

The method based upon the behavior of neutralized solutions at the boiling point (Fresenius, page 362), which we personally prefer to use, is open to the same objections. The process of

separating the iron by ammonium hydrate, even with all the precautions recommended by various authors, has given very unsatisfactory results in our hands. By far the best success was obtained in the use of the method given by Frederick Field, in the Chemical News, vol. i, page 5 (1859). The method is as follows:

"In the case of nickel and iron, the nitrates are evaporated nearly to dryness, and, after the addition of water, oxide of lead (litharge) is added, and the whole boiled for ten minutes or a quarter of an hour. The iron is entirely precipitated, the nitrates of nickel and lead remaining in solution. After filtration, which can be effected with great readiness, dilute sulphuric acid is added, and on standing for sixteen hours the sulphate of lead is filtered off, and the nickel precipitated and estimated in the usual manner."

This process uniformly gave good results as to the separation of iron and nickel, all the nickel being left in solution. The presence of lead in the solution was somewhat undesirable, the results being too high if the nickel was weighed as oxide, and much more caution was required in the battery precipitation. All these methods require two or three days, and the quantity of the ore or matte to be operated upon is limited, usually two to four grams.

Among the numerous tests made for a more ready way were those depending upon the solubility of the sulphates in alcohol and upon the behavior of the oxalates, but no satisfactory results were reached. Finally a systematic series of tests was made with the phosphates, in the course of which it was found that phosphate of nickel is completely soluble, while phosphate of iron is almost insoluble in acetic acid, in the presence of an excess of phosphate of soda. Upon this fact, which we had not found mentioned in any work that we had consulted, we based the following process.

The ore or matte is dissolved in hydrochloric acid with the addition of a little nitric acid. All the metals of the arsenic and copper groups, if present, are separated by means of hydrogen sulphide with the usual precautions. The filtrate is boiled to drive off the excess of hydrogen sulphide, the iron is oxidized by nitric acid, and ammonium hydrate is added until a permanent precipitate begins to form, but not until complete precipitation is effected. Acetic acid is then added until the precipitated ferric hydrate is redissolved and the liquid is of a deep red color, though not transparent. To this boiling hot solution ordinary phosphate of soda is added in excess, and the nearly white precipitate is filtered and washed with hot water containing acetic acid. The filtrate is heated nearly to boiling and caustic potash added until the odor of ammonia is distinctly

perceptible. The apple-green precipitate of phosphate of nickel is partially washed, dissolved in a little *dilute* sulphuric acid, the solution rendered strongly alkaline by ammonium hydrate and the nickel precipitated by the battery.

If the ore contains more than three per cent of nickel, it is necessary to dissolve the precipitate of phosphate of iron in hydrochloric acid, dilute this solution somewhat, render it nearly neutral by ammonium hydrate, add twenty-five or thirty cubic centimeters of acetic acid, and re-precipitate by phosphate of soda. The filtrate is added to the first filtrate. If the solution has been rendered alkaline before the addition of acetic acid, or if an insufficient quantity of phosphate of soda has been used a small amount of iron will remain in the solution, not enough, however, to interfere with the battery precipitation of the nickel. The solution of phosphate of soda should be a saturated one, and, if it is heated separately, the troublesome boiling of the bulky precipitate is avoided. By the aid of the filter pump this precipitate is readily filtered in spite of its unpromising appearance.

The advantages of this method are: 1st, the concentration of the solution. It may contain ten to fifteen grams of ferric oxide in a half liter, instead of one gram as in the basic acetate method, and thus larger quantities of a poor ore may be operated on. 2d, A great saving of time. The nickel may be weighed in eight or ten hours from the time the ore is pulverized and ready for solution. This saving of time is mainly due to two causes. First, less care is required in case of precipitating as phosphate than as basic acetate. Second, in precipitating phosphate of nickel by caustic potash it is not necessary to concentrate the solution nor to expel all the ammonia as is the ease in precipitating as hydrated oxide. An unexpected advantage is the more ready battery precipitation of the nickel from the solution of the phosphate.

Two of the so-called quart carbon cells, each half filled with the solutions (bichromate of potassium and sulphuric acid) were found quite sufficient to precipitate the nickel completely in two hours. If a strong current was used, the nickel was precipitated in a black, spongy form.

A solution containing ·375 grams Ni as chloride, and 1·183 grams Fe as chloride was made up to 250 c. c.

	Found.	Theory.	per cent.
100 c. c. of which	·1486	·150	99·06
100 c. c. "	·149	·150	99·33
50 c. c. "	·0748	·075	99·73

To the first portion, the phosphate of soda was added first, and the acetic acid afterward.

		per cent.	
Matte No. 1 gave	(phosphate method)	6·77	Cheney.
	" "	6·86	Richards.
	" "	6·48	Richards.
Matte No. 2 "	(neutralized solution)	2·08	Richards.
	" "	2·37	Richards.
		2·15	Cheney
Matte No. 3 "	(phosphate method)	7·22*	Richards.
	" "	7·41†	Hardman.
	(basic acetate)	7·79	Hardman.
Pyrrhotite No. 1	(basic acetate)	·32	Hardman.
	" "	·29	Hardman.
" "	(phosphate method)	·33	Cheney.
		·25	Cheney.
Pyrrhotite No. 2	(phosphate method)	·725	Richards.
		·686	Richards.

Massachusetts Institute Technology, Woman's Laboratory, June, 1877.

ART. XXIV.—*Notes on the internal and external structure of Paleozoic Crinoids;* by CHARLES WACHSMUTH.

(Continued from page 127.)

5. *The construction of the summit and its value in classification.*

THE construction of the ventral disc or actinal side of the calyx has heretofore received less attention than almost any other part of the Crinoids, and thereby an important aid to classification has been overlooked. I think it affords a clear and most important distinction between recent and ancient Crinoids, and shows that they fall naturally into two great divisions or groups. This view, although it does not agree with the opinion of other authors, who, in their classifications, have placed a number of Paleozoic genera in the same group with the recent Crinoids, is, as I hope to show, well founded.

Dr. F. Roemer, in the Lethæa Geognostica, 1855, p. 227, divides "*the true Crinoids*, which are supported by an articulated or jointed column" into two divisions:

a, Crinoids in which *the ventral side consists of a soft skin.*

b, Those in which *the ventral side is covered by solid immovable plates.*

Rœmer includes with the former group, *Pentacrinidæ*, *Apiocrinidæ*, *Eugeniacrinidæ*, *Encrinidæ*, *Cupressocrinidæ* and *Cyathocrinidæ*. This division seems to have been based on mere conjecture, since a membranous ventral surface has been observed only in the Pentacrinidæ and the recent Crinoids generally,

* Mrs. Richards lost a portion of the washings by the breaking of a beaker.

† This was Mr. Hardman's first trial of the phosphate method and not enough phosphate of soda was added to produce a *white* precipitate.

though it is probable that *Eugeniacrinus* and several allied genera had that summit structure. In the Apiocrinidæ and Encrinidæ however, the general construction of the dorsal or abactinal parts, the massive plates, both of calyx and arms, indicate rather a closer relationship with the ancient Crinoids and suggest the existence of a solid dome. The latter becomes more probable since a solid vault has been discovered in *Belemnocrinus*. This genus is in its generic formula and general form almost identical with the recent *Rhizocrinus*, which on the contrary is covered by a soft peristome. Both are closely related to *Apiocrinus; Belemnocrinus* particularly has the same heavy body plates and the small visceral cavity, and it appears to me that *Apiocrinus* is more nearly allied to the Paleozoic type than to the recent *Rhizocrinus*.

The *Cupressocrinidæ* and *Cyathocrinidæ* are the only groups from Paleozoic formations which Rœmer places in his division *a*. Dr. Schultze, who adopted Rœmer's classification, included in the *Cupressocrinidæ* the genera "*Synbathocrinus* Phill. and *Phimocrinus* L. Schl.," in which he is undoubtedly correct, for stronger reasons even than he himself perceived. These two genera agree with *Cupressocrinus* not only in the simplicity of their arms, but also in the so-called "consolidating apparatus," which he describes and figures in the latter. The apparatus is placed horizontally in *Cupressocrinus*, upright and turbinate in the two other genera. When the consolidating plates in *Synbathocrinus* are preserved, the ventral side appears to have two separate apertures, a lateral proboscis and a central mouth. And so the genus was originally described. This is, however, a misconception. By removing carefully all the arm joints from a specimen of *Synbathocrinus*, I discovered the central aperture perfectly covered with a number of small plates, and to this summit, as it might be called, were attached narrow lateral extensions, composed of alternating pieces, which passing downward, covered the little grooves that lead to the arm furrows. The consolidating apparatus here forms in fact a part of the solid vault. It is reasonable to conclude, that in the allied genera *Cupressocrinus* and *Phimocrinus*, so closely related to *Synbathocrinus* otherwise, the central opening was closed, and that the consolidating plates were further overlaid with plates forming the floor of a passage in connection with the arm furrows and visceral cavity. The small plates which extend out to the arms are in the specimen but partly preserved and the connection with the arm-furrow is interrupted, but there can be no doubt that the channel underneath contained the food groove and ambulacral canal which I have described in *Cyathocrinus*. The covering of the central opening of *Synbathocrinus* resembles in a remarkable degree that of the central aperture of the *Blas-*

toids, and it seems to me highly probable that the consolidating plates are homologous with the partly hidden deltoid pieces of the latter.

Among the Cyathocrinidæ, Rœmer included genera of widely different types. Besides the typical one, he enumerates nine genera, only two of which, *Heterocrinus* and *Graphiocrinus*, have the characteristics of the *Cyathocrinidæ*, and both of them evidently possess a solid dome, as is proved by their heavy proposcis. All the remaining genera belong to other groups. *Macrostylocrinus* resembles *Ctenocrinus* Bronn, and *Cytocrinus* Rœmer so closely, that they may yet prove to be identical. Rœmer, however, places *Ctenocrinus* with *Glyptocrinus* among the Crinoids with a solid dome, and *Macrostylocrinus* among the *Cyathocrinidæ*. *Macrostylocrinus* is allied to *Melocrinus*, and has undoubtedly a similar summit structure. The same may be said of *Schizocrinus* and *Dimerocrinus* which are not at all related to *Cyathocrinus*.

The genus *Cyathocrinus* was originally described by Professor Phillips and Mr. Austin as having a separate mouth and vent, which was considered by these authors and others to be its chief distinction from *Poteriocrinus*. Accordingly, all species with a proboscis or solid dome, though otherwise agreeing with *Cyathocrinus*, were referred to *Poteriocrinus* or some allied genus. Meek and Worthen, however, proved in the Geological Report of Illinois, vol. v, p. 325, that in perfect specimens, the central opening is closed. The covering of *Cyathocrinus* is exceedingly interesting, and throws light upon the summit structure of many genera. I shall herein refer frequently to Meek & Worthen's excellent figures, vol. v, Plate IX, figs. 13 and 14.

Looking only at fig. 14, one would at first naturally suppose there must have been, during the life of the animal, two distinct openings in the vault. But on examining it more critically and comparing it with fig. 13, it will be found that fig. 14 represents simply the consolidating apparatus as figured by Rœmer and Schultze in *Cupressocrinus*, placed here exactly as in that genus, and consisting of five large pieces, alternating with the upper edges of the first radial plates. The plate of the anal side is larger than the others and forms the base of the inner side of the proboscis. The five pieces which connect with each other laterally, extend inward for some distance, but not so far as to meet in the center where there is a semi-circular or heart-shaped opening. Along the sutures, between the five plates, a comparatively large furrow from each arm base extends inward and leads to the central opening. Examining now fig. 13 we find the general aspect of the ventral disc entirely changed. The lateral opening has been transformed into

the base of a proboscis, and the consolidating plates are partly covered, leaving but a small uncovered space in the form of a delta in the interradial areas. The central opening is vaulted over by a number of various sized pieces, the largest one occupying the side toward the proboscis. The shallow groove between the sutures of the consolidating plates is arched by a double series of alternating plates, forming underneath a passage for the ambulacral canal and food groove. The vault, thus closely resembling that of *Synbathocrinus*, was in all probability arranged on a similar principle in *Cupressocrinus*. The same plan, with slight modifications, prevailed in *Poteriocrinus*, *Scaphiocrinus* and all genera with an *inflated or balloon-shaped ventral sac*. Among the latter, the center of radiation is frequently found to be pushed toward the anterior side, so that owing to the great size of the sac at its junction with the dorsal cup, it does not occupy the center of figure.

Among all groups of Crinoids, the *Cyathocrinidæ* undergo the least amount of change in the course of time. They are represented in the lower Silurian by several genera, and *Cyathocrinus* is the only genus recognized in the Permian. In all intermediate formations, we find Crinoids with five basals, five subradials and five radials, and it is worthy of note that the *Cyathocrinidæ*, in the structure of their vault, bear closer resemblance to the recent Crinoids than almost any other group, and seem to hold an intermediate position between modern and Paleozoic types. If the alternating plates, covering the furrows, could be turned back at the vault by the animal, as the Saumplatten of the arms, then the food groove of these Crinoids was open throughout, as in recent forms. This might possibly have been the case in *Cyathocrinus Iowensis*, but I even doubt it here, as the corresponding plates in other closely related species, though arranged upon the same fundamental plan, present rather an aspect of true vault pieces. The *Cupressocrinidæ* and *Cyathocrinidæ* thus fall naturally into a group by themselves, having the vault supported by consolidating plates, and covered by an immovable arch of small plates.

The next group is one in which of all Paleozoic Crinoids the vault is least known, including *Taxocrinus*, *Forbesiocrinus*, *Onychocrinus*, *Ichthyocrinus*, *Lecanocrinus*, and probably other genera. The *Taxocrinidæ*, for such I will call them, have hitherto been described as being covered with some soft material instead of solid plates, even by Dr. Schultze, though he describes and figures a *Taxocrinus* with a long heavy plated proboscis, which could not have been supported upon a soft skin. * In this

* I believe Dr. Schultze is mistaken in referring his *T. briareus* to *Taxocrinus* as it lacks all the characteristic features of the genus. Its rather large subra-

group, the plates of the radial series are indented on their upper margins more or less deeply for the reception of a protuberance from the lower side of the succeeding plate. The indentation of the upper margin does not extend throughout the thickness of the plate, and in *Forbesiocrinus*, it is filled by a superficial patelloid plate, which is separately articulated and sometimes anchylosed with the outer margin of the plate above. This peculiarity exists not only in the arm plates, but is conspicuous in the radials, thus producing apparently an articulate structure of the whole skeleton and indicating some degree of flexibility in the body as well as the arms. The interradial portions appear sometimes depressed, and in other cases swollen or bulged out, showing that they probably yielded to a moderate expansion or contraction of the body walls, due to the mobility of the radial parts which likewise involves a flexibility of the summit. I have not been so fortunate to find the summit of any of these genera perfectly preserved, but I feel convinced from what I have observed, that it did not consist of a soft skin. In *Onychocrinus*, the genus which possessed evidently the greatest expansive power, the radial plates are frequently found spread out horizontally, and I have found toward the inner or ventral side of the radials, rather large imbricating plates, to which smaller ones are attached which connect with the plates of the interradial series, and which decrease in thickness inwardly. In several specimens I found the inner part or center of the disc covered by a number of thin, very small plates, whose arrangement could not be made out, but it is highly probable from their size and shape, that they formed a kind of scaly integument which was pliant and flexible, thus facilitating a contraction or expansion of the dorsal portions.

The close relationship existing between *Onychocrinus*, *Forbesiocrinus* and *Taxocrinus*, renders it almost certain that their summit was similarly constructed. In *Ichthyocrinus* the peculiarities in the radial portions are less strongly marked, and the genus has no interradial plate, but as it agrees otherwise so nearly with *Taxocrinus* that it is sometimes difficult to separate them, we may feel sure that this *Silurian* genus forms no exception to the general rule, but that its mouth was covered as in other Paleozoic Crinoids.

That the summit in several genera has not been discovered is no proof that it consisted of soft material. During the eighteen years that I collected at Burlington, I obtained several hundred of the most perfect specimens of *Cyathocrinus*,

dials, the large first-radials as compared with the succeeding radials, the single anal plate upon which the heavy proboscis rests, indicate that it belongs to *Cyathocrinus* or some allied genus. His *T. gracilis* may prove to be *Graphiocrinus* or *Scaphiocrinus* (?).

some of them as perfect in most of their parts as if dredged from the ocean, but only two specimens have been discovered in which the summit was preserved, and only a single *Scaphiocrinus*. That this could happen at a locality where even the finest tissues of the most delicate internal organs are preserved, is somewhat astonishing, but yet it can be accounted for by the fact that the pieces which cover the central opening, as also the small alternating plates forming the ambulacral canal, are very thin and that they rest but partly upon the consolidating plates, being thereby rendered insecure and liable to removal by any accident, even with very small force. Moreover the arms of the *Cyathocrinidæ* are generally attached, and the ventral disc thus hidden from view. In specimens in which the arms are destroyed, their destruction almost invariably involved that of the entire ventral side, and so delicate are these parts, that even when the arms are well preserved and so situated as to expose the dome, the plates are nearly always gone, or are found in a confused mass inside the calyx.

I come now to another group in which on the basis of the summit structure, such apparently diverse forms are included that I am under the necessity, very unwillingly, of making a name for it. It includes the families *Actinocrinidæ*, *Platycrinidæ*, *Rhodocrinidæ*, *Melocrinidæ*, and the genera *Schizocrinus*, *Dimerocrinus* and *Macrostylocrinus*, which Rœmer has ranged among the *Cyathocrinidæ*, and I call it provisionally the *Sphæroidæ*, from the form of the calyx which is generally somewhat spherical. This large group, embracing over one hundred genera and ranging from the base of the Silurian to the top of the Subcarboniferous, is capable of accurate definition, is easily distinguished, and fortunately the summit is very commonly found well preserved in most of the genera.

The summit is composed of heavy, frequently nodose plates, closely cemented together, so as to form a *free arch* (not supported by consolidating plates), which rests like a hemisphere upon the dorsal cup. The plates of the summit, which at first sight exhibit great apparent diversity, are arranged throughout upon one and the same fundamental plan. Beginning with genera that have but few vault pieces, we find in them the median portion occupied by one large center plate, surrounded by six others, four large ones of equal size, and two smaller ones. The four large plates join laterally and are often placed directly to the center piece. In very large species and sometimes in very old specimens, the plates are separated by small polygonal pieces, but easily recognized by their size. Two of the four plates lie above the interradial series adjoining the anterior ray, the two others, one at each side, are placed between the two lateral rays. The two smaller plates are separated from each

other by anal plates or by the proboscis. These seven pieces which I will call the "*apical plates*," are easily recognized by their greater prominence and size in species with comparatively few summit plates and a lateral anal aperture; but their identification is more difficult in species in which a subcentral proboscis is placed between the two small plates, and the whole vault looks like an immense proboscis. In these forms, the four large plates, together with the two smaller ones, are pushed toward the anterior side of the specimen, while the center plate rests with one side against the proboscis.

There are other summit plates following a radial direction, which are either attached to the apical pieces or separated from them by a belt of small polygonal plates. Their number, which varies greatly in different species, depends upon the number of primary arms that spring out directly from the body, no matter how often the arms branch afterward. In species with only two arms to the ray, each ray has two rows of corresponding plates in the dome, one large bifurcating plate forms the upper row, three plates the second row; two of the latter are brachial plates, the third one is an inter-brachial plate separating the two arms. In rays with three arms, there are eight plates in three series. The upper series consist of one large bifurcating plate which evidently corresponds with the third radial of the dorsal side. The second series, corresponding to the secondary radials, is composed of two plates, the plate toward the division with two arms being as large as the plate of the upper series, and the one toward the single arm much smaller. The third series is formed by three brachial and two interbrachial plates. In species with four arms to the ray, both radial pieces of the second series are large, and from each of them there originate two brachial pieces. As a general rule, the summit plates increase in proportion to the number of primary arms of a species in the same manner and on the same principle as the plates of the dorsal side. Every radial from the third radial upward has a corresponding plate on the ventral side, and additional interbrachial plates between corresponding brachial plates above the arms. Therefore in adult specimens, with some little practice, the number of arms can be ascertained nearly as well from the dome as from the dorsal side. The number of vault pieces is enormous in some genera, especially if the radials branch off alternately, as for instance in *Strotocrinus*, where some species have 120 to 180 arms. In looking at a full grown specimen, with its many hundred apparently irregularly arranged vault pieces, one would scarcely expect to be able to discover that this construction, in nearly all the Paleozoic Crinoids, is based upon a definite plan, and that plan the same as prevails below the arms.

That this is the case may be successfully demonstrated in the *young Strotocrinus* which has comparatively fewer summit plates.

The young specimen, in genera with numerous arms, has fewer arm openings than the adult, though both have the same number of arms. This is best observed in the young *Strotocrinus*. Here, the basals, primary radials, first anal and first interradial pieces are comparatively large, while the higher series of interradials are yet absent or but slightly developed. The radials of the higher orders, which in adult specimens form a part of the body, are in young specimens free arm plates, unsupported by any interradial or interaxillary pieces. The arms, therefore, which spring directly from the body in adult specimens, in the young branch alternately right and left after emerging from the body, the spaces between the bases of the branches being subsequently filled by the upward growth of the body, so that the branching, instead of occurring in the free arms, seems to be completed in the body walls. So, for instance, the young *Strotocrinus umbrosus* has at first but four arm openings to the ray, at a later period it is found to have eight, and in the adult state twelve, being a separate opening for each arm.*

The rule, that the number of summit plates increases in proportion to the number of primary arms, holds good with reference to the young specimen. The young *Strotocrinus* has fewer plates than the adult individual (the difference being in proportion to the state of growth), and these are arranged in the same order, and are as easily recognized as those of the simplest species of this group. The apical and principal radial pieces are larger than the intervening interradial plates which, exceptionally in this genus, attain by age the same size as the apical and radial pieces. *The interradial plates* of the vault occupy the intermediate spaces between the radial areas. As their number depends greatly upon the age of the individual, they vary often in the same species. In species with but few arms, we find comparatively few interradials, and those are generally smaller than the other plates. The latter is especially true in young specimens, as also in small species. Sometimes, as for instance in some *Megistocrini* and all *Rhodocrinidæ*, the greater part of the summit is covered by large numbers of small polygonal plates which form regular belts around the apical and radial plates. The species of these genera, though

* A young *Strotocrinus*, unless the arms are attached, cannot be distinguished generically from an adult *Actinocrinus proboscidialis*, and as both have the same peculiar ornamentation with the same number of arm openings, they differ but slightly in specific characters. *Actinocrinus proboscidialis* is the typical species of a small group of beautifully ornamented Crinoids, and is evidently the forefather of all *Strotocrini*, which idea seems to be further confirmed by the geological succession. The former group occurs only in the *Lower*, and *Strotocrinus* only in the *Upper* Burlington limestone.

being comparatively of large size, have generally but two primary arms, and consequently for each ray but one radial dome plate which is here placed at some distance from the arm bases. In the *adult Megistocrinus* the radial as well as apical plates are extremely large and stand forth conspicuously, and each one separately, among the surrounding minute polygonal pieces. In the *young Megistocrinus*, however, and in the *Rhodocrinidæ* generally, the apical pieces and the radial plate are placed side by side, being surrounded by the polygonal plates. The form and size of the principal summit plates, the distribution and number of the interradial pieces, afford most excellent characters for distinguishing many genera. In *Agaricocrinus*, all apical and radial pieces are large and tuberculous, the few interradials are small. In *Dorycrinus*, the center plate and first radials are spiniferous or nodose. In *Amphoracrinus*, the four large apical pieces are spiniferous or tuberculous, the radials nodose. In *Platycrinus* and *Hexacrinus*, the apical plates are very prominent, often tuberculous, the radial portions are somewhat constructed like the rows of small alternating plates of the *Cyathocrinidæ*. In *Batocrinus*, all summit plates are nodose and almost of equal size.

The apical plates can be distinguished in other groups as well as in this. They surmount the vault of *Synbathocrinus* and *Cyathocrinus*, cover the central opening of the Blastoids, and can be traced in many of the Cystideans. This, with the further fact that they are so largely developed in young specimens, that they cover and protect some of the most important organs of the inner cavity, shows their great importance, and leads us to infer that they were the first solid parts developed on the ventral side in young Crinoids. The center piece corresponds evidently with the basals of the dorsal side, the surrounding plates to the subradials (the two smaller plates, separated by the anus forming together one large one), which on the other hand were undoubtedly the first developed parts of the dorsal side, and the parts which are the most highly developed in the Cystideans.

The above groups, representing the three principal plans upon which the vault is constructed, embrace, according to my views, not only all those Paleozoic genera which were supposed to be covered by a membranous surface, but nearly all Paleozoic Crinoids that are known. There are some few genera, as for instance *Eucalyptocrinus*, with a very peculiar superstructure at the ventral side, whose affinities I have not been able to determine. There is the genus *Calceocrinus* which differs so widely from all other known Crinoids by its distinct bilateral symmetry and unique structure, that it forms evidently a very distinct group by itself. There may be still others, differing in

their summit structure from the general plan; but I have yet to discover a single Paleozoic genus in which a special oral aperture has been identified, or in which the existence of a solid vault has been disproved, or cannot be traced by analogy. Thus it may be possible that the solid vault was essential under the conditions which prevailed in the earlier geological ages.

Closely related as the recent Crinoids are to their Paleozoic ancestors in some points, the solid vault of the latter cannot in the remotest degree be homologized with the soft peristome of the former. The solid dome forms, as I think I have proved, a continuation of the radial and interradial series of the dorsal side and serves merely as a covering and protection for the organs underneath. It is in every sense of the word aboral and forms a part of the abactinal system, which being already reduced in the *Pentacrinidæ* and *Comatulidæ* to a narrow tentacle furrow, recedes in Paleozoic Crinoids one step further and disappears within the solid walls of the body. The actinal system here consists externally only of the arm furrows, whence it continues underneath the vault. These Crinoids therefore are evidently of lower development and belong to an inferior type.

The ventral peristome of the recent Crinoids serves as a madreporic apparatus, introducing the necessary water for respiration. It is capable of expansion, and does expand when water or food is introduced into the inner cavity, and contracts when refuse matter is expelled. These are functions which the solid vault could not have performed, and there must have been consequently important modifications in the internal economy of these animals. Comparing the large size of the calyx of the *earlier* Crinoids with the small cup and large long arms of the *recent* types, we find in the former an approach to the *Cystideans*, as also a striking resemblance to the nascent *Pentacrinus* before its arms are fully developed. In the older forms, the radial plan is almost overshadowed by the bilateral arrangement of the vault, which reminds of the bilateral symmetry in the earlier stages of other Echinoderms. All these facts tend to prove, that the *Paleozoic Crinoids*, embracing therein all *true Crinoids in which the actinal side is closed*, represent the young stage of growth of the living types. They bear evidently the same relation to the *Pentacrinidæ* and *Comatulidæ* as the *Perischoechinidæ bear to the Echini, as the Cystideæ and Blastoideæ bear to the Paleozoic Crinoids.* They unquestionably form a *distinct group* of Crinoids, and I therefore propose for it, from the fact that its representatives lived almost exclusively in Paleozoic times, the name: "*Paleocrinoidea*" *as a suborder of the Crinoids.*

Whether *Encrinus, Apiocrinus* and allied genera of the Jurassic time are to be brought within this suborder, depends upon the construction of their vault, which cannot at present be de-

termined. Should they prove to have a solid dome they would be included here, and this might detract slightly from the technical exactness of the name *Paleocrinoidea*. Still as its characteristic types were so prevalent and constituted so important a part of the life of Paleozoic ages and the Mesozoic forms are comparatively so insignificant in variety and abundance, the term would nevertheless be significant and appropriate.

I shall not attempt to separate the *Paleocrinoideæ* into families, as I think our present knowledge is hardly sufficient for such a work, but I feel convinced that it must be based mainly upon the diversities in the structure of the vault, not upon the construction of the dorsal cup, nor upon the structure of the arms or column, upon which former authors have founded such divisions.

The discoveries which have been made within the last few years, both in recent and extinct Crinoids, are really wonderful, and lead us to expect large additions to our knowledge in the future. I observe in the February number of this Journal, that Professor Thomson has discovered at great depth two new genera of *Apiocrinidæ*, one of them resembling in superficial structure the genus *Poteriocrinus*. This may throw new light upon the physiology of the extinct types and solve some of the questions herein suggested. Other discoveries will follow. The labors of the Zoologist will supplement the researches of the Paleontologist and through their properly united efforts, we may hope in time to comprehend the structure of the *Paleocrinideæ* almost as perfectly as if they were yet living in our oceans.

Art. XXV.—*On some Phenomena of Binocular Vision;* by Joseph LeConte.

X. *The structure of the crystalline lens and its relation to Periscopism.**

The following thoughts were suggested by the recent memoir of Dr. Ludimar Hermann "On the passage of luminous pencils obliquely through lenses, and on a related property of the crystalline lens of the (human) eye,"† in connection with my own recent publication "On the comparative physiology of Binocular Vision."‡

It is well known that the crystalline lens of the mammalian eye increases in density and refractive power, from the surface to the center; so that it may be regarded as composed of ideal

* Read before the National Academy of Sciences, April, 1877.

† Archives des Sciences, vol. lii, p. 66. ‡ This Jour., vol. ix, p. 168, 1875.

concentric layers, one within another increasing in density and in curvature until the central nucleus becomes a very dense and highly refractive spherule.

Evidently this structure must have some important use in vision or it would never have been formed; but the question of its design has never been satisfactorily settled. It is usually regarded as intended to correct spherical aberration. It certainly is useful in this way, *when the pupil is greatly expanded.* But in strong light, when the pupil is greatly contracted and therefore only central rays reach the retina, *correction is not needed*, because, even in a homogeneous lens, *aberration*, under these circumstances, is *inappreciable.* It is natural, therefore, to cast about for some other purpose subserved by this very curious and universal structure.

Very recently Dr. Hermann (loc. cit.) has discovered another optical property conferred upon the lens by this structure—a property which he regards as of great importance in perfect vision, and which, therefore, he thinks, entirely explains the design of the structure. It is the property of *forming images of objects lying on the margins of the field of view, far more perfect than could be formed by a homogeneous lens* of the same focal distance. And since, as he supposes, perfect images of marginal objects necessitates distinct vision of these objects, he calls a lens having this structure *periscopic.*

By mathematical discussion he shows that, in a homogeneous lens, while the central rays *from radiants near the middle of the field of view*—i. e., of pencils nearly parallel with the axis of the lens—are brought to a perfect focal point, the central rays, from *marginal radiants*—i. e., of very oblique pencils—form crossing caustic lines. The refraction in the former case is *stigmatic*, in the latter *astigmatic.* Therefore the picture formed by such a lens is distinct in the central parts and very indistinct on the margins. Now this well known defect of a homogeneous lens Dr. Hermann shows is certainly in a great measure, probably entirely, *removed by the structure peculiar to the crystalline lens.* For in the case of a lens composed of concentric laminæ increasing in density and curvature to the center, the astigmatism of oblique pencils is greatly diminished, and if the laminæ be infinitely thin, probably entirely removed. The picture formed by such a lens would therefore be perfect in all parts, even to the extreme margins. *The crystalline lens, therefore, by its structure is endowed with the property of forming distinct images of objects lying even on the extreme margins of the field of view—of forming perfect images on all parts of the retinal screen even to the extreme anterior margins.* It is this structure, according to Dr. Hermann, which gives the eye its enormous field of view, compared with that of optical

instruments. This then is the purpose of this structure. *It gives periscopism to the eye.*

Such is a brief statement of Dr. Hermann's discovery, and his deductions therefrom. This discovery I regard as very important, but his deductions in regard to periscopism of the human eye cannot be received without important modifications. For it can be shown that so far as periscopism is concerned, the peculiar structure of the lens is of little, if any, value in man, *for want of a corresponding suitable retinal structure.*

In order to show this, it is necessary carefully to distinguish two kinds of indistinctness of vision, viz: that which results from *indistinctness of the retinal image*, and that which results from *imperfect perception* of the image. The former has its cause in the properties of the lens, the latter in the organization of the retina. We may have a very perfect perception of an imperfect image, and on the other hand we may have so imperfect a perception of an image that we cannot tell whether it is perfect or not. If, for example, I hold the point of my pen very close to one eye (shutting the other), and look at the sky, the pen point is very indistinct, because the retinal image is indistinct; but my perception is perfect. I *can observe with great accuracy the exact degree of indistinctness.* This is an example of one kind of indistinctness of vision. But if I hold my pen far to one side, on the extreme verge of the field of view, say 90° from the direction of the optic axis, the pen is again indistinct, far more so than before, but from an entirely different cause, viz: *imperfect perception* of the retinal image. My perception, in fact, is so imperfect that I cannot tell whether the image is distinct or not. This is an example of the other kind of indistinctness of vision.

Now of these two kinds of indistinctness, the latter is by far the greater. Objects on the margin of the field of view are perceived as objects, and nothing more; their form cannot be distinguished—they attract attention, but we must turn the optic axis on them or near them in order to tell what they are. For example, held at arm's length and 90° from the usual line my pen is seen only as an elongated object; at 60° the shape is still indistinguishable—neither the point, nor the hole through the back, can be seen at all, though projected against a bright sky. Only at 30°–40° these begin to be distinguished. Even within a few degrees of the optic axis the *perception* of form is still very imperfect. In this case, however, the indistinctness is wholly the result of imperfect perception, not of imperfect image. I cannot perceive whether the image is perfect or imperfect—whether the outlines are blurred or sharply defined.

It is evident, therefore, that the retina of the human eye is so organized (and as I have shown in my previous article,* it is

* Loc. cit.

important that it should be so organized), that the perception of its images, good or bad, is most perfect in the central spot, and thence becomes less and less perfect toward the anterior margin, where it finally becomes extremely imperfect. Evidently, therefore, with this extremely imperfect marginal perception, extremely perfect marginal images would be entirely useless. *Periscopic structure of the lens is useless because periscopic perception of the retina is wanting.*

True periscopism, i. e. the power of distinct vision over a wide field without changing the direction of the optic axis, is therefore a product of two factors, viz: 1st, a periscopic property of the *lens*, i. e. of *making* distinct marginal as well as central images; 2d, a periscopic property of the *retina*, i. e. of distinctly *perceiving* marginal as well as central images. Now, Dr. Hermann has left out the second factor, and thus identified periscopism of the lens with periscopism of the eye.

I think it quite certain, therefore, that the property of making distinct marginal images, and therefore the characteristic lens structure, *in so far as it subserves this purpose*, is useless in *man*. Yet it seems equally certain that this property is a very important one. Where then shall we seek its use, and what is its significance in man? I believe we must seek its use in the lower animals, where it originated. In man it must be regarded as an example of *a structure which has outlived its usefulness.*

We have already shown in our last paper (p. 170), that true periscopism, or distinct vision over a wide field, is a necessary condition of safety in many of the lower animals. In accordance with the law of evolution, therefore, an ocular structure, suitable for this purpose, must be gradually formed and perfected. This ocular structure, as we have just seen, consists of two parts, a *lens* structure to produce perfect marginal images and a *retinal* structure to produce equal perception of all images, central and marginal. Both of these were developed in the highest degree in many of the lower animals, as for example in the ruminants. But in the highest animals, and especially in man, as we have shown in the paper referred to, this equal distribution of perception is inconsistent with fixed attention and thoughtful observation, and therefore with the development of the higher faculties of the mind. The uses of distinct marginal perception, viz: breadth of distinct view, are sacrificed to the higher uses of distinct central perception alone, viz: fixed thoughtful attention to the object regarded alone. Thus with the development of the *central spot* of the retina, *distinct marginal perception* is lost; because the uses of the latter are inconsistent with the higher uses of the former. But the other factor of periscopism, viz: the property of forming distinct marginal images, is retained by inheritance; because though no longer

useful in this way, it is in nowise hurtful and may even be useful in other ways.

But I have also (loc. cit.) shown the close relation between the development of the central spot and the consequent loss of periscopism, and the development of true binocular vision. Hence it is evident that, in going up the vertebrate scale, just in proportion as the central spot is developed, and the position of the eyes is adapted for binocular vision, the characteristic structure of the lens, in so far as it is designed to produce perfect marginal images, becomes useless. There may be, however, and probably are, other uses, (e. g. correction of aberration), which this structure subserves and which would tend by natural selection to keep up the structure. It would be extremely interesting in this connection to compare the lens of the human eye with that of the eye of the ruminants. In so far as it subserves the purpose of periscopism the characteristic structure ought to be less marked in the human eye, since its retention is due to inheritance alone, and not to natural selection. If it is not less marked there would be strong reason to suspect that periscopism is not the most important purpose of this structure.

Berkeley, Cal., Jan., 1877.

ART. XXVI. —*On Ethylidenargentamine-ethylidenammonium Nitrate;* by W. G. MIXTER. *Contributions from the Sheffield Laboratory of Yale College.* No. XLIX.

LIEBIG, in his researches on aldehyde,* examined the precipitate obtained by mixing concentrated solutions of aldehyde-ammonia and silver nitrate. His analysis of it shows an atomic relation of silver 1, carbon 4, and hydrogen 11. He failed to estimate nitrogen and hence did not obtain a formula, but concluded from the deportment of the compound with acids and alkalies that it contained aldehyde, ammonia and nitric acid.

I have not succeeded in getting a good product for analysis by mixing simple aqueous solutions of aldehyde-ammonia and silver nitrate. Decomposition began before the substance could be washed with alcohol. This decomposition is, however, prevented, by using ammoniacal solutions. The substance is soluble in one and one-half parts, or less, of concentrated ammonia water, and is still less soluble in pure water. In the first experiment with ammoniacal solutions, the ammonia was rapidly removed by a blast of air, and from equal weights of aldehyde-ammonia and silver nitrate, two crops of very small white crys-

* Liebig's Ann., xiv, 147.

tals were obtained, which were washed with alcohol, and dried over oil of vitriol. The carbon and hydrogen were determined by burning with lead chromate, the nitrogen by Schiff's method with copper oxide and displacement of air by a slow stream of carbonic acid, and the silver by simple ignition. The following results were obtained from the two crops above mentioned:

	1st crop.	2d crop.	Mean.	Atomic ratio.	Calculated for $C_4H_{10}N_3O_3Ag$.
Carbon	18·32	18·33	18·33	3·9	18·75
Hydrogen	4·31	4·16	4·23	10·8	3·91
Nitrogen	16·63	16·65	16·64	3·	16·41
Silver	42·06	41·99	42·03	1·	42·18
Oxygen			18·77	3·	18·75
			100·00		100·00

These results give a formula different from $NO_3Ag\ 2(C_2H_3ONH_4)$, which is given in Watts' Dictionary, vol. i, p. 108, as probably representing the substance. Taken together with Liebig's analysis, they also indicate that the same body is formed in both aqueous and ammoniacal solutions.

$C_4H_{10}N_3O_3Ag$ differs from two equivalents of aldehyde-ammonia and one equivalent of silver nitrate by two molecules of water, thus: $2(C_2H_4ONH_3)+AgNO_3-2H_2O=C_4H_{10}N_3O_3Ag$. This view of the chemical process is supported by the reactions of aldehyde with benzamide and aniline, in which water separates, and also by the following experiment: 29·2 grams of a mixture of silver nitrate and good crystals of aldehyde-ammonia, in the proportion of one equivalent or 17· grams of the former, to two equivalents, or 12·2 grams of the latter, were dissolved in 40 c. c. of concentrated ammonia-water. The solution was evaporated in a weighed dish, first by a blast from a laboratory bellows and finally over oil of vitriol until the weight was constant. The residue weighed 25·445 grams. The weight, according to the above formula, should have been 25·600 grams. The difference of 0·155 grams between the experimental result and theory may be ascribed to the slight decomposition the substance had undergone in drying, which was shown by the small black residue it left when treated with ammonia-water.

When an ammoniacal solution of aldehyde-ammonia and silver is evaporated at 20° to 30°, hydrous monoclinic transparent crystals separate, which do not change rapidly on damp days, but become opaque with loss of water in dry weather. Together with the hydrous crystals, small poorly defined triclinic crystals form which do not become opaque in dry air. The latter are transparent and colorless, or more frequently have a resinous tinge. Dr. E. S. Dana has studied the crystalline form of both the hydrous and anhydrous crystals, and gives his re-

sults in the following paper, Art. XXVII. The hydrous crystals can be picked out before losing their luster if the atmosphere is damp, and the anhydrous crystals are easily distinguished after the former have become opaque. The following results were obtained on good monoclinic crystals which had been dried over oil of vitriol, and on transparent anhydrous crystals:

	Monoclinic dried crystals.	Triclinic crystals.	Calculated for $C_4H_{10}N_2O_3Ag$.
Carbon	18·55	18·62	18·75
Hydrogen	4·08	4·12	3·91
Nitrogen	16·58	16·64	16·41
Silver	42·03	41·97	42·18
Oxygen			18·75
			100·00
Specific gravity,	2·13	2·28	
Melts with rapid decomposition at	130°–135°	125°–130°	

To determine whether the monoclinic substance lost any ammonia on drying, nearly two grams of crystals, not entirely free from the triclinic body, were heated to 100°, in air which traversed a caustic potash drying tube before reaching the substance and then passed a weighed tube filled with fragments of caustic potash. The substance lost in weight exactly what the latter tube gained, and the water thus estimated corresponded to 4·20 per cent. The following results were obtained by drying well selected monoclinic crystals in a desiccator at 20° to 30°:

0·383	gram	lost	4·28	per cent.
0·343	"	"	4·26	"
0·437	"	"	4·23	"
1·0504	"	"	4·24	"

After the 0·383 gram had obtained a constant weight in the desiccator it was exposed for half an hour to 60° without further loss; in three quarters of an hour at 100° the loss increased 0·0025 gram and the crystals had become brown. These water determinations lead to the troublesome formula for the monoclinic hydrous crystals, of $8(C_4H_{10}N_2O_3Ag)+5H_2O$, which represents 4·21 per cent of water.

Both kinds of crystals are soluble in water, very soluble in ammonia water, almost insoluble in alcohol, sparingly soluble in ammoniacal absolute alcohol, and both give a silver mirror when their aqueous solutions are heated, and but a trace of silver remains in solution after continued boiling. With hot potash solutions both forms give the same odor that is perceived when aldehyde-ammonia is treated with potash. Dilute acids set aldehyde free, and warm oil of vitriol evolves nitrogen peroxide fumes. Both turn brown at 100°, the monoclinic crystals remain brittle, but the triclinic substance becomes gummy at

100° after some time. The triclinic crystals decompose rapidly a few degrees lower than the monoclinic. Both kinds appear to be permanent in dry air. On recrystallizing the monoclinic variety some triclinic crystals appear, and the triclinic form yields on recrystallization some monoclinic crystals.

As to the constitution of the bodies their reactions make evident that they contain the ethylidene and nitro groups. They are plainly analogous to the ammonio-silver nitrate, which crystallizes from a mixture of silver nitrate with excess of ammonia water as all contain (exclusive of crystal water) 3 atoms of nitrogen and 3 atoms of oxygen to 1 of silver. We may therefore, regard them as amines, and may show their relation to ammonia-silver nitrate as follows:

$$\left.\begin{matrix} H_3N \\ H_3N \end{matrix}\right\} AgNO_3 \qquad \left.\begin{matrix} CH_3{-}CH{=}NH \\ CH_3{-}CH{=}NH \end{matrix}\right\} AgNO_3$$

In accordance with the requirements of the now received theories, these bodies may be formulated as substituted ammonium nitrates, viz:

$H_4{\equiv}N{-}O{-}NO_2$, ammonium nitrate.

$$\begin{matrix} H_3{\equiv}N{-}O{-}NO_2 \\ H_3{\equiv}N \\ | \\ Ag \end{matrix}$$ argentamine-ammonium nitrate.

$$\begin{matrix} H \\ CH_3CH{=}N{-}O{-}NO_2 \\ H \\ CH_3{-}CH{=}N \\ | \\ Ag \end{matrix}$$ ethylidenargentamine-ethylidenammonium nitrate.

ART. XXVII.—*On the crystalline form of the hydrous and anhydrous varieties of Ethylidenargentamine-ethylidenammonium Nitrate;* by EDWARD S. DANA.

A. *Hydrous Ethylidenargentamine-ethylidenammonium Nitrate.*

THE hydrous variety of ethylidenargentamine-ethylidenammonium nitrate, described by Professor Mixter in the preceding article, crystallizes in the *monoclinic* system. The observed planes (see figs. 1, 2) are as follows:

c (001), *d* (111), *g* ($\bar{1}11$), *e* (011), and rarely *b* (010).

From the measurement of a considerable number of crystals the following were obtained as the fundamental angles:

$$c\,(001) \wedge e\,(011) = 69°\ 2'$$
$$c\,(001) \wedge d\,(111) = 78°\ 35'$$
$$d\,(111) \wedge d'(1\bar{1}1) = 60°\ 50'$$

From these angles the elements of the crystals were calculated, viz:

$$\dot{c} : \bar{b} : \dot{d} = 4{\cdot}32645 : 1{\cdot}65788 : 1{\cdot}00000$$
$$\beta = 89°\ 43'\ 52''$$

Other important angles, calculated from the same data, are as follows:

$$c\,(001) \wedge g\,(\bar{1}11) = 79°\ 2'$$
$$g\,(\bar{1}11) \wedge g'(\bar{1}\bar{1}1) = 60°\ 56'$$
$$d\,(111) \wedge g\,(\bar{1}11) = 114°\ 17'$$
$$d\,(111) \wedge e\,(01\bar{1}) = 66°\ 18'$$
$$g\,(\bar{1}11) \wedge e\,(01\bar{1}) = 65°\ 5'$$
$$d\,(111) \wedge e'(0\bar{1}\bar{1}) = 122°\ 56'$$
$$g\,(\bar{1}11) \wedge e'(0\bar{1}\bar{1}) = 122°\ 48'$$
$$d\,(111) \wedge b\,(010) = 59°\ 35'$$
$$g\,(\bar{1}11) \wedge b\,(010) = 59°\ 32'$$

The measured angles agreed quite closely with the calculated angles when the character of the planes was such as to admit of satisfactory observations. This will be seen from the following examples, being the angles measured on different crystals for $d \wedge d'$ and $c \wedge c$:

$d \wedge d' = 60°50', 60°47', 60°46', 60°47', 60°51', 60°52', 60°50'$, etc.
$c \wedge d = 78°35', 78°39', 78°40', 78°33', 78°34', 78°40', 78°38', 78°36'$, etc.

In many cases, however, the planes were by no means satisfactory, being generally polished and yet far from smooth, and hence the reflections given by them were more or less uncertain. The planes g, g' were quite uniformly striated, and hence the measurements made upon them were always unreliable. The following angles were all obtained from a single crystal; the wide variations from the calculated angles observed in some cases are due to the cause named:

$c \wedge d = 78°\ 27'$	$d \wedge g = 114°\ 12'$	$d \wedge d' = 60°\ 46'$
$c \wedge d' = 78°\ 38'$	$d' \wedge g' = 114°\ 7'$	$g \wedge g' = 60°\ 46'$
$c \wedge g = 78°\ 10'$	$d \wedge c = 65°\ 52'$	$g \wedge e = 65°\ 41'$
$c \wedge g' = 78°\ 30'$	$d' \wedge c' = 66°\ 23'$	$g' \wedge e' = 66°\ 33'$
$c' \wedge e = 69°\ 3'$	$d \wedge e' = 122°\ 51'$	$g \wedge e' = 122°\ 57'$
$c' \wedge e' = 69°\ 2'$	$d' \wedge e = 122°\ 30'$	$g' \wedge e = 123°\ 33'$

The crystals examined were quite small, averaging from one to two millimeters in length. The are generally rhombic

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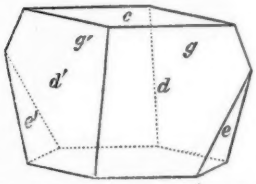

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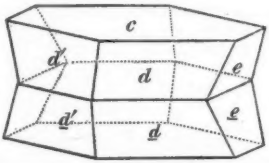


(fig. 1) at one extremity, and hexagonal in outline on the other; occasionally, however, from the extension of the clinodomes they take the form of hexagonal tables (fig. 2). The hemihedral character of the crystals, shown in the figures, is a marked feature which they all possess. No trace of either of the missing pyramids or clinodomes was in any case discovered; a few isolated crystals of apparently holohedral development were without exception found by optical means to be twins, though showing no reëntrant angles. Other twins had the form of fig. 2. The twinning-axis is here a normal to the basal plane.

The cleavage is highly perfect parallel to the base (*c*), and the crystals have a pearly luster on this face.

The examination of the optical properties of the crystals proves that, though the angle of obliquity is small (89° 44′), they unquestionably belong to the *monoclinic* system, and, on the other hand, that they are not triclinic.

A natural crystal, or still better a cleavage section, viewed in the polariscope in a direction normal to the basal plane (*c*), shows the biaxial interference figures most satisfactorily. The axes, however, do not lie in the center of the field, but slightly on one side in the direction of the pyramids *d*, *d′*; thus showing that the plane of the optic-axes is not quite normal to the base. The *horizontal* dispersion is also very strongly marked.

A section cut parallel to the clinopinacoid and examined in the polariscope of Groth, shows that the acute bisectrix for blue rays makes an angle of 8° with a normal to the base (*c*), being inclined forward (see fig. 1) toward *d*, while the same angle for red rays is $5\frac{1}{2}°$.

The apparent optic-axial angle in air was obtained with considerable exactness:

$2E=68°\ 23'$ for red rays, $=67°\ 30'$ for blue rays. The ordinary dispersion is consequently $\rho>\upsilon$; the dispersion of the bisectrices, on the other hand, $\upsilon>\rho$. The character of the double refraction is *negative*.

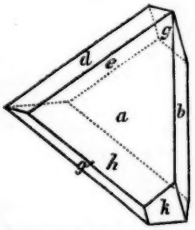
The twins (see fig. 2) gave interference figures of great beauty, both sets of axes being visible, situated symmetrically on either

side of the medial line. The apparent angle between the two axial planes, measured in the usual way, was found to be 31° for blue and 25° for red. The true angles corresponding to these, obtained with the stauroscope, are 16° and 11° respectively. The first-mentioned angles, however, are not sufficiently accurate to serve for the calculation of one of the indices of refraction.

B. *Anhydrous Ethylidenargentamine-ethylidenammonium nitrate.*

The crystals of the second, or anhydrous, variety of this compound belong to the *triclinic* system. Unfortunately the material which Prof. Mixter has thus far been able to put into my hands has been much too imperfect to allow of exact determination. The crystals are small and the planes uniformly rough and uneven, so that the measured angles with an occasional exception cannot be relied upon within less than 30′.

3.



The crystals are quite uniform in habit, and figure 3 represents as closely as possible the common form. The crystal is placed in the position given in order to exhibit the close approximation to the *monoclinic* form. *e*, *g*, *h* are planes of the lower side, and *a′* is opposite *a*.

The angles measured on one crystal are as follows:

$a\,(100) \wedge d(1\bar{1}1) = 57°\ 20'$ $\quad a\,(100) \wedge g(\bar{1}11) = 65°\ 10'$

$a'(\bar{1}00) \wedge h(\bar{1}\bar{1}\bar{1}) = 58°\ 2'$ $\quad a'(\bar{1}00) \wedge e(\bar{1}\bar{1}1) = 64°\ 4'$

$g\,(\bar{1}11) \wedge e(\bar{1}\bar{1}1) = 65°44'$

These angles point to a form having an obliquity in a vertical direction of about 5°, but very slightly inclined in a horizontal direction. The measurements for $a\,(100) \wedge b\,(010)$ gave in the best case 90° 10′, and again 90° 20′. The variation from 90° is here within the possible error of observation, owing to the imperfect character of the planes; the question was not decided, consequently, until a stauroscope examination showed that the plane of vibration for the light was not normal to *b* (010), but made an angle of about 18°, thus proving the *triclinic* nature of the crystals.

The measured angles, as has been stated, are not sufficiently reliable to give the axial ratio calculated from them any especial value; the approximate values of the axes are, $\breve{c}=1{\cdot}45$, $\bar{b}=1{\cdot}93$, $\breve{a}=1$. The hemihedral character of the crystal figured is true of all the crystals, and the examination in the stauroscope failed to show any evidence of twinning. The crystals were not suited for any further optical examinations.

ART. XXVIII.—*On the relations of the Geology of Vermont to that of Berkshire;* by JAMES D. DANA.

[Continued from page 140.]

CONCLUSIONS AS TO THE RELATIONS OF VERMONT AND BERKSHIRE GEOLOGY.

THE conclusions, which flow from the fact, illustrated in the two preceding numbers of this Journal, that the limestone areas of Vermont and Berkshire are geologically one, may be presented under the following heads:

1. Chronological conclusions: or the equivalence and age of the formations.
2. Lithological conclusions.
3. Orographic conclusions.

And, as a sequel to this discussion, I propose, next, to present stratigraphical facts bearing on the geological relations between the area which has been under consideration and the country lying to the southward and eastward of it, in Connecticut and New York.

I. CHRONOLOGICAL CONCLUSIONS: OR THE EQUIVALENCE AND AGE OF THE FORMATIONS.

1. *Age of the Limestone series as a whole.*—From the facts brought forward it is manifest that the limestone, schists and quartzyte, making up the limestone series of Vermont and Berkshire, are *continuous* formations, and that they are *conformable* throughout. Hence we have proof that the conclusions deduced for Vermont, from Mr. Wing's discoveries, are true also for Berkshire: namely, that—

(1.) The limestone series is *made up wholly of Lower Silurian formations;* that is, of formations not older than the Primordial or Cambrian, nor newer than the Cincinnati or Hudson River group.

(2.) All these formations were upturned and metamorphosed together at one mountain-making epoch, no epoch of disturbance having intervened; and that upturning occurred after the laying down of the most recent of the formations in the series.

2. *Age of the Taconic slates, and of the limestone immediately adjoining.*—The Taconic mountains of western Berkshire are a direct continuation of the "Great central slate-belt" of Vermont. The two make one range and one rock-formation, and consist of the same kinds of rocks similary upturned. They are alike also in dividing off a western band of limestone from the main limestone area—that extending through West Cornwall in Vermont, and that of Hillsdale, Copake and Millerton, in New

York. In Vermont the Taconic slates (those of the central slate-belt) *overlie* the adjoining limestone in one or more synclinals, as plainly shown in Mount Dorset, Danby Mountain, Equinox Mountain, Spruce Peak in Arlington, and Mount Anthony in Bennington; and in Berkshire they have the same position, as observed in Graylock and Mount Washington. Hence in both States *the Taconic slates overlie, or are younger than, the adjoining limestone.*

In Vermont, as Mr. Wing has shown, the limestone nearest the slate contains, in several places, Trenton fossils (*Trinucleus*, etc.), and at West Rutland, Chazy fossils (*Maclurea*, etc.) if not also Trenton; and the slates are, therefore, as has been already stated, *younger* than the Trenton limestone of that region and belong probably to the Hudson River or Cincinnati group. If this be true in Vermont, the Taconic range in Berkshire, since it is part of the same slate-belt, consists of rocks younger than the Trenton, and is therefore either of the *Upper Trenton or of the Hudson River or Cincinnati group.*

It may be questioned whether the Graylock Spur should be included with the Taconic range, since it stands to the east of it. But the resemblance in its rocks to those of the Taconic range, coupled with its position stratigraphically *above the adjoining limestone*, just as in Mount Anthony, Equinox Mountain, Mount Eolus and other peaks in the slate-belt of Vermont, make it almost certain that the age of one is the age of the other, as first observed by Emmons.

The Berkshire *limestone* of the band adjoining the Taconic range is mostly, if not wholly, non-magnesian, like that of Vermont. Hence its constitution, as well as its position, makes it altogether probable, that it is Trenton or Chazy, as in Vermont. The limestone *west* of the Taconic range in Hillsdale, Copake and farther south, must also be Trenton or Chazy since this is true for that similarly situated in Vermont; and, moreover, it is the west side of one and the same synclinal flexure, the limestone on the east side of the Taconic range passing beneath and coming up again on the west side.

3. *The Limestones and Schists of the Eastern half of the limestone area.*—Like the Taconic slates to the westward, these more eastern rocks in Berkshire are a continuation of those north of them in Vermont. The quartzyte is not all in one range in either State; but, whether in one or several ranges, it is alike from north to south in belonging especially to the more eastern part of the limestone area. Hence whatever is true of the age of the quartzyte in one State is almost certainly true in the other.

Further, whatever the range of age in the more eastern of the limestones of Vermont, the same is the probable range of that in Berkshire and farther south. Like the Vermont limestone

then, the Berkshire limestone of the middle and eastern half of the area may include the Calciferous, Quebec, Chazy and Trenton formations, and perhaps also the Primordial; but, since there are no fossils to fix the precise age, the areas of these different formations in Berkshire cannot be separately distinguished.

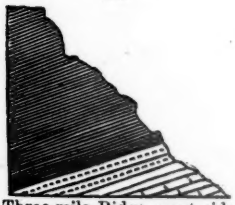
4. *The age of the Quartzyte formation, and its relation in position to the adjoining limestone.*—The quartzyte formation includes, as has been explained, strata of quartzyte and schists—sometimes one, and sometimes the other, predominating. The special age of the formation is in doubt, equally with that of the eastern limestones. There may be quartzytes of different periods of the Lower Silurian; and so with the schists. The question of age can be positively answered only by the discovery of decisive fossils in the quartzytes of Vermont; and so many imperfect forms have already been brought to light (besides the unsatisfactory worm-burrows, and Fucoids or worm-tracks) that we may feel sure the future will clear away the doubts. A word is added beyond (p. 207) on two of the forms thus far discovered.

One important point—the position of the quartzyte with reference to the associated limestone—is well illustrated in Berkshire. Mr. Wing, in his explanations of the Vermont sections (pp. 410, 411 of the last volume of this Journal), makes this limestone to *overlie* the quartzyte, and to be the equivalent of the "subcrystalline limestone" which overlies the Red Sandrock on the west side of the limestone area—the quartzyte being in his view the same rock with the Red Sand-rock. It is to be noted, however, that the sections themselves do not indicate whether the limestone is overlying or underlying, and may be explained as well on one supposition as the other.

In Berkshire, beyond all reasonable doubt, *the eastern quartzyte formation overlies the adjoining limestone.*

The most distinct and positive proof of the superposition of the quartzyte over limestone that I have observed is that

19.



Three-mile Ridge, west side of Konkaput Valley.

20.

Devany's Quarry, east side of Konkaput Valley.

afforded by sections either side of Konkaput Valley—a locality brought to my attention, as I state in my memoir of 1872–3, by Dr. R. P. Stevens. The figures of the sections of Devany's

Bluff and Three-mile Ridge, which face one another on opposite sides of the valley, are here repeated from page 45 of this volume. In each of the sections, quartzyte strata and overlying schists of great thickness rest on the limestone which outcrops in the valley. The dip is small (8°–25°, p. 46). The limestone is plainly at the bottom; and *it is stratigraphically* so, unless there has been a flexing of the strata and an overturned fold at the place. Nothing in the region suggests that there has been such an overthrow: the facts, on the contrary, prove the flexure which the strata have undergone to be a gentle one. As has been stated, the two ridges stand opposite one another, not quite a mile apart. In the eastern, the dip is 20°–25° to the northeastward; in the western, about the same to the northwestward. The series of rocks from below upward, limestone, quartzyte, schist, of one side, is repeated in the other, and the schist of the west side has a thickness of several hundred feet like that of the east. All the conditions are those of a low anticlinal spanning the valley; and one whose axis dips gently northward, and whose sides flare southward or southward and eastward. The valley south of Devany's Bluff widens much to the eastward and has its lakes with limestone about them.

Besides this, the rocks of the gentle anticlinal are continued in the high land either side in a broad shallow synclinal—the high land synclinals and the anticlinal valley between covering a breadth from east to west of ten miles. (*a*) In the synclinal to the *west* (between the Konkaput valley and Great Barrington), the schist has first a dip northwestward of 8° to 25°, but, after three-fourths of a mile, the dip is eastward 20° to 25°, and finally 40° to 50°, just east of Great Barrington. (*b*) In that to the *east*, the dip is 5° to 25° to the northeastward, over the high land and mountainous region all the way east from Devany's bluff to the village of Monterey; but on the northeastern side of this high land, at the village of Tyringham, and at South Lee, it is to the southwestward. A section between Monterey and Tyringham, east of north in course, shows the change of dip. The limestone about Monterey dips 25° to the northwest; along the highest part of the road, the gneiss and mica schist of the hills outcrop and have the same dip and strike; descending to Tyringham, five miles to the north, the dip diminishes, and for the last mile is reversed, being to the southwestward; finally, at Tyringham, the limestone comes into view again overlaid by the same kinds of gneiss and mica schist, with a dip of 15° to 25°.

Thus, both *east* and *west* of the Konkaput anticlinal there is as gentle a synclinal; and hence the idea of an overturn cannot be reasonably entertained. It appears to be a general rule, for the eastern or quartzyte part of the limestone area as well as the western, that *the valleys are eroded anticlinals*, and *the ridges*

or areas of high land are synclinals, a rule exemplified extensively in the continuation of the Appalachians from Pennsylvania to Alabama, where the facts are little obscured by metamorphism. The position of the limestone *beneath* the quartzyte and schists along the Konkaput is then the original position.

This underlying of the thick quartzyte and schists by limestone appears to be a fact in many other parts of the Berkshire region, as in Monument Mountain, in quartzyte ridges east of Tom Ball, and elsewhere, though these examples are not as free as the above mentioned from other supposable explanations. The evidence is complete with or without them, that *the quartzyte and the associated schists in some prominent cases in Berkshire, if not all*, overlies limestone. In such cases, accordingly, the limestone is the older formation of the two; and this is as true for Vermont as for Berkshire. And where so in either State the quartzyte and the associated schists constitute *synclinals or monoclinals—not anticlinals.*

There is another argument favoring the view that the quartzyte is in *synclinals.* It may be questioned whether lofty anticlinals of quartzyte are a possibility. The quartzyte was originally a deposit of sand, or a sandstone, of great thickness. Now such a sand-bed or sandstone, raised into a close and lofty anticlinal flexure so as to have, as in Vermont, and in some parts of Berkshire, a dip of 40° or 50°, would be sure to have been very profoundly broken by the strain; and thus broken, it would have been exposed to erosion and destruction, and even to removal so as to leave a valley in its place, as has been the usual fact in the Appalachians; while, if bent up into a synclinal, whether shallow or deep, the pressure would tend to promote compactness, consolidation, and preservation. Hence the existence of the quartzyte formation in lofty ridges is strongly against its being in anticlinals.

If then the quartzyte ridges are not anticlinals, *the limestone is the inferior stratum.*

Again: if the quartzyte is Primordial, the underlying limestone is inferior Primordial. Consequently, the quartzyte formation should be elsewhere found separating this inferior Primordial limestone from the limestones of the Calciferous, Quebec, Chazy and Trenton periods. But the fact is that this limestone which underlies the quartzyte is in many places in Vermont continuous with the rest of the limestone formation, one area of limestone stretching from the quartzyte quite to the Taconic slate-belt where are Trenton and Chazy fossils in it. We naturally inquire—how under these circumstances can it be that the quartzyte formation belongs any where between the Trenton and that inferior limestone? Is it not necessarily superior to all the continuous Lower Silurian limestone formation? But if thus superior, the quartzyte is not Primordial; it is not the

equivalent of the Red Sandrock; it is even related in age to the Taconic slates; these overlying a western portion of the limestone and the quartzyte formation an eastern. If so, *the eastern quartzyte formation is of the age of the later Trenton, or the Cincinnati group, both in Vermont, Berkshire and Connecticut.*

It will be remembered that the axis of the iron-ore belt is situated in the vicinity of the quartzyte in Vermont, but in the vicinity of the Taconic range in Berkshire; and even west of the Taconic range for the region south of the latitude of middle Berkshire (this vol., p. 133). Thus the quartzyte and the Taconic slates have the same geological relation to the iron ore belt; and this again suggests the idea that the two are of the same age—both of the Cincinnati or Hudson River group if one is.

These remarks make apparent the difficulties and doubts surrounding the question as to the age of the quartzyte, doubts which only new discoveries of fossils can wholly set aside.

The collections of Yale College contain specimens of the "Modiolopsis" and "Orthoceras" reported by the Vermont Report as occurring in the Quartzyte, which were received by me from the late Professor Adams, many years since, when he had charge of the earlier uncompleted survey of that State. There is but one specimen of each—not enough for a decided opinion about them. Quite recently I have seen other specimens in the Amherst College Museum. One is a piece of quartzyte with many casts of one valve of the so-called "Modiolopsis;" and another contains several of the "Orthoceras;" and I have found that both are unquestionable fossils. The former is the shell of a small lamellibranch about six and a half lines long and five broad. The so-called *Orthoceras* is a slender conical tube filled with quartzyte; and it was apparently without septa —no remains of them being present within; the specimen in the Yale collections has a length of 0·6 in.: a diameter, at the larger (broken) end, of 0·24 in., and, within a twentieth of an inch of the smaller rounded end, of just half this. It appears to be a *Theca*-like species. The lamellibranch seems to indicate, as Professor James Hall concluded, that the quartzyte is not Primordial, and that it must be later in age.

The facts that have been reviewed have established: (1) The Lower Silurian age of the limestone series as a whole; (2) the unity of position, and of epoch of uplift, of the series; (3) the very probable Trenton and Chazy age of the limestone adjoining the whole of the Taconic slate-belt or range; (4) the equally probable Upper Trenton or Cincinnati age of the Taconic rocks. But the age of the more eastern portion of the limestone and of the quartzyte and schists remains undetermined. My opinion is that the quartzyte will be found to be newer than the Red Sandrock, and of the same age essentially as the Taconic slates.

[To be continued.]

ART. XXIX.—*On the preparation of Cylinders of Zirconia for the Oxy-hydrogen Light;* by JOHN CHRISTOPHER DRAPER, M.D., LL.D., Professor of Natural History in the College of the City of New York.

SUCCESS in the use of the microscope for the purpose of projecting magnified representations of microscopic objects on a screen depends primarily upon the light employed, especially when high powers are used, as for example, a quarter inch objective. To answer the purpose in question the light must possess: 1st, intrinsic brilliancy; 2d, the brilliancy must be as nearly as possible invariable; 3d, it must retain its fixity of position in the optical axis of the apparatus.

If the experimenter has a good heliostat, the light from the sun fulfills these conditions better than any artificial light; but, experience teaches the unwelcome lesson that though sunlight is preferable to any other, it scarcely ever happens that it is available at the time it is wanted. The weather is almost certain to be either cloudy or hazy just at the hour when it is desired to make an important demonstration, and the lecturer is obliged to postpone it, thereby lessening its value, and often entirely losing its effect. The selection of the best artificial light therefore becomes a matter of importance to those who desire to secure the advantages to be derived from the successful demonstration of such microscopic objects as preparations of animal and vegetable tissues, animalcules, the circulation of the blood, etc.

The artificial lights possessed of sufficient intrinsic brilliancy are: 1st, the electric arc or light; 2d, the magnesium ribbon light; 3d, the oxy-calcium light; 4th, the oxy-magnesium light; and 5th, the oxy-zirconium light. The first has greater brilliancy than any other in the list, but in addition to fifty or one hundred cups of a nitric acid or bichromate battery a good regulator is also necessary; this involves a very considerable expenditure of money, and even when this is made, the labor and trouble required to manage the battery, and the continued change in the part of the carbon electrodes between which the arc of light passes renders its use unsatisfactory.

The magnesium ribbon light has the great disadvantage of the emission of fumes of oxide, which coat the surface of the condensing lenses in spite of all attempts to dispose of it otherwise. The light also is not concentrated on a small fixed surface; but, is emitted from a varying length of ribbon.

The oxy-calcium light produced by projecting the flame of mixed oxygen and hydrogen gases upon a cylinder or pencil of calcium oxide is the one generally employed. It is fixed in

its position in the optical axis of the apparatus, it is thrown into operation with comparative facility when cylinders containing the compressed gases are available, and it has sufficient intrinsic brilliancy for the majority of experiments. The difficulties in the way of its use are however serious, and it is very desirable that they should be lessened. They arise chiefly from the volatility of the calcium oxide at the intensely high temperature employed. The volatilized material depositing on the condensing lenses prevents the passage of the luminous rays, and the cavity formed in the cylinder of lime at the spot where the flame impinges soon interferes with the brilliancy of the light; this necessitates a change in the position of the lime cylinder to present a new surface to the action of the flame, and this in its turn implies a distraction of the attention of the experimenter, which interferes seriously with the satisfactory management of his subject. Though the attempt is made to avoid this difficulty by clock work, or other mechanical contrivances, they are still unsatisfactory in their action. Another serious objection is the necessity of placing the cylinders in a closed vessel when not in use to protect them from the action of the air.

The oxy-magnesium light is similar to the preceding, differing only in the substitution of a cylinder or pencil of magnesium oxide for calcium oxide, and the light emitted is of equal brilliancy. Following the instructions given for the preparation of these cylinders, I have taken the greatest pains to procure samples of magnesium oxide of the utmost purity. I have also tried various methods for its preparation, among which the combustion of the metal in oxygen may be mentioned, but failure has thus far attended all efforts to make pencils or cylinders which could withstand the intense heat of the flame of the mixed oxygen and hydrogen gases without undergoing volatilization. The pencils obtained were fully equal in this respect to those of calcium oxide; but, I did not find any superiority that repaid the trouble of their preparation.

The oxy-zirconium light produced by the action of the flame of mixed oxygen and hydrogen gases on a cylinder of zirconium oxide meets all the requirements of the case in question. It has the intrinsic brilliancy, the invariable brilliancy, the fixity of position in the optical axis of the apparatus, and it does not volatilize under the heat employed. The condensing lenses remain free from deposit, and after the light is once adjusted the experimenter can carry on his demonstrations without the distraction of his attention that attends the use of the other lights. All that is necessary is according to the size of the reservoirs of compressed gas to open the cocks a little as the pressure diminishes. There is also no necessity to remove

the zirconium oxide pencil from its position, as is the case with the calcium oxide, it may on the contrary remain *in situ* for any length of time, and the apparatus is always ready for use whenever it is wanted.

Though the standard works on chemistry generally mention the light-emitting power of zirconium oxide under a high temperature, the only successful attempt that has been made to apply it practically that I am aware of was that of Tessié du Motay. Unsatisfactory references to his process for preparing zirconia cylinders are to be found in various chemical works and journals, the best that I have seen being that given on page 47 of "Crooke's Select Methods in Chemical Analysis." The careful reader of this and other articles on zirconia will be prepared to expect difficulties in the way of its preparation, and it is to the removal or lessening of these difficulties that I now propose to address myself by the minute relation of the process I have finally adopted after many weeks of experiment.

The subject naturally divides itself: 1st, into the preparation of zirconium oxide; and, 2d, the preparation of the cylinders or pencils.

Preparation of zirconium oxide.

The compound of zirconium used is that known as the zircon of North Carolina. It is essentially zirconium silicate, and the composition of this and other specimens of zircon will be found in Dana's Mineralogy. The difficulty in the operation consists in the complete removal of the silica and of the sodium compounds used in the disintegration of the mineral.

1st. Select the zircon crystals or fragments thereof of as light a color as possible, and carefully remove all attached foreign matter; provide about ten grams in weight.

2d. Reduce five or six grams to powder in a steel mortar; or, by first heating to bright redness and chilling in water while very hot the same may be done in a porcelain mortar. Remove any mica or other foreign matter that may appear.

3d. Complete the pulverization in an agate mortar, introducing small quantities at a time, and reduce to an impalpable powder. The final yield of zirconia depends on the thoroughness with which this is done.

4th. Weigh out two grams of the fine zircon powder and mix it intimately in a mortar with ten grams of dry sodium carbonate, place the mixture in a covered platinum crucible of twenty cubic centimeters capacity.

5th. Place the crucible over a strong Bunsen flame; the burner should be at least fifteen millimeters in diameter; in about twenty minutes the mass in the crucible will have shrunken to one-third of its original volume if the heat is sufficient. To secure uniformity in temperature of the crucible

I have employed the following device. The platinum crucible being placed in a triangle of platinum wire supported on the ring of a retort stand, a graphite crucible having a diameter of five centimeters was taken and an opening fifteen to twenty millimeters in diameter made in its bottom. It was then placed mouth downward over the platinum crucible, with its mouth at the level of the bottom of the latter, and resting on the same support. A brass or iron tube two and a half centimeters in diameter and six to eight decimeters in length was placed vertically over the bottom of the graphite crucible, resting on it and enclosing the opening previously made therein. A furnace was thus constructed, the long tube being the chimney, giving a good draught, and the graphite crucible the body which confined the flame to the surface of the enclosed platinum crucible and heated it equally.

6th. The shrinkage of the mass having been satisfactorily accomplished it is to be fused; for this purpose a powerful gas blowpipe flame urged by a foot bellows answers very well. In place of the ordinary blowpipe flame I have used a modification contrived by my assistant, Mr. Ivin Sickels. It consists of a large Bunsen burner two centimeters in diameter, the upper opening is closed by a cap through which seven small tubes pass, each having a diameter of two and a half millimeters. The lower openings of the burners are also closed except one through which a tube passes and communicates with a foot bellows. Coal gas being turned into the burner, ignited, and the bellows thrown into action, seven clean sharp pointed blowpipe flames are produced which give a very intense heat.

The mass in the platinum crucible having been fused and the fusion continued until it begins to assume a pasty state, it is again liquified according to the plan of Berzelius by the addition of caustic soda about equal in weight to that of zircon. The heat being again applied the disintegration of the silicate continues, and if necessary a second addition of caustic soda may be made.

7th. The contents of the platinum crucible having cooled, separate them therefrom, and place in a beaker, add two hundred cubic centimeters of distilled water; any portions of the fused material that adhere to the walls or cover of the crucible are also to be removed by a jet of distilled water and added to the contents of the beaker. An occasional stirring will promote the disintegration of the mass, which is completed in the course of a couple of hours, silicate of sodium, the excess of sodium carbonate and soda dissolving, and leaving a white powder, which according to Dr. Melliss is composed of zirconium oxide, silicium anhydride, and sodium oxide, together with any zircon that may have escaped disintegration.

The contents of the beaker are thoroughly stirred and set aside for twenty-four hours to settle. The clear supernatant fluid is decanted, another two hundred cubic centimeters of distilled water added, the mixture stirred and set aside for twenty-four hours or longer, and when the precipitate has settled the liquid is decanted and the beaker with its contents set on the water bath to dry.

8th. Pulverize the dried material in the beaker with a glass rod, add twenty cubic centimeters of pure hydrochloric acid (Merck's), cover the beaker with a large watch glass and set on the water bath; when the acid has dissolved as much as it will take up, it is to be decanted while hot into a shallow evaporating dish of about five hundred cubic centimeters capacity. A second dose of twenty cubic centimeters of hydrochloric acid is added to the contents of the beaker, and when all lumps are broken down the mixture is transferred to the evaporating dish, a little hydrochloric acid being used to complete the transference.

9th. For the final separation of the silica the contents of the dish are evaporated to dryness on the water bath, and the heat continued until they cease to emit acid fumes, a little distilled water is then added and thoroughly incorporated with the residue by stirring. The mixture is again evaporated to dryness at 212° F. The second drying being completed, about two hundred cubic centimeters of distilled water are added, and when all the soluble material is taken up the mixture is transferred to a filter. On the filter there remains silica and undecomposed zircon. In the filtrate there are zirconium chloride, sodium chloride and iron chloride.

10th. The next step is the separation of the zirconium chloride from the iron chloride, and as completely as possible from the sodium chloride. This I have accomplished as follows. The filtrate being made up to five hundred cubic centimeters with distilled water, washed sulphurous acid gas is passed through the fluid as long as a precipitate forms, or until the contents of the flask smell strongly of sulphurous acid. The mixture is then boiled as long as it emits any odor of sulphurous acid, the loss of liquid being made up from time to time by the addition of distilled water. The precipitate of zirconium sulphite is allowed to settle for a day or two and is then collected on a filter, where it must drain for a day, the funnel being covered with a sheet of paper. As it is impossible to wash the precipitate properly on the filter, it must be carefully transferred therefrom to a beaker while it is still moist by means of a glass rod and jet of distilled water from a washing bottle. The lumps being completely broken up the contents of the beaker are again made up to five hundred cubic centimeters with dis-

tilled water well stirred, and when the precipitate has settled it is collected on a filter as before and allowed to drain as long as it will yield any fluid.

11th. The precipitate obtained above is dissolved in as little pure hydrochloric acid as possible, the solution diluted with distilled water to five hundred cubic centimeters and heated to boiling for some time. Ammonia is added to the hot solution, when the zirconium oxide is thrown down and is to be collected on a filter, washed with hot water and allowed to dry at the temperature of the air, the yellowish or whitish lumps resulting are pulverized in an agate mortar, when a white powder is obtained. The quantities I have given in the various operations detailed above apply to two grams of the powdered zircon. For the preparation of a zirconia cylinder of sufficient size the product obtained from four grams of zircon is required, the quantities may be doubled throughout; but, it is better to make two fusions of two grams each and double the quantities given in the latter part of the description.

I have also tried the separation of zirconium chloride from iron chloride by hydrochloric acid; but, though I worked at a temperature of 32° F., the yield was very small and therefore unsatisfactory. In the process by hyposulphite of soda I found it very difficult to get rid of the soda. The process of disintegrating the zircon by chlorine at a high temperature also failed to give satisfactory results in my hands, and I find that Dr. Melliss records the same experience.

Preparation of the Cylinders.

The zirconium oxide powder obtained in the manner described above is to be heated in a platinum crucible and kept at a bright red for five or six hours; it will under these circumstances shrink considerably in volume. I have sometimes in addition submitted the powder to the heat of the oxy-hydrogen flame with advantage, spreading it out for this purpose on a piece of platinum foil supported on a slab of iron, and directing the flame on the powder. The operator should wear smoked spectacles. The powdered oxide thus condensed by heat is then moistened with just enough water to give it a tendency to form small lumps. In this condition it is placed in a cylindrical mould and submitted to severe pressure by a piston fitting closely to the cavity of the cylinder, both of which should be properly oiled. The size of the pencils I have prepared is about six millimeters in diameter and one centimeter in length. When in use they are mounted so as to present one end to the action of the oxy-hydrogen flame, when a brilliant circular spot of light is formed admirably adapted for all kinds of optical experiments.

The cylinder in which the pencils have been compressed is about two centimeters in diameter and four centimeters in length; the cavity running centrally through it is six millimeters in diameter, the piston rod fits closely, and both it and the cylinder are of hardened steel; the source of compression is a small hydraulic press, and the pressure employed is about two tons. The pencil is forced from the cylinder after compression by the press itself, and is very hard. It is allowed to dry slowly and is then ready for use. When first heated the temperature is gradually increased until at last the full force of the oxy-hydrogen jet is employed. In case the pencil chips or loses any part of its substance the portions are to be preserved and ground up with old pencils in an agate mortar mingled with a little fresh zirconia powder and compressed in the cylinder. The pencils thus obtained from portions of older ones are generally superior to those made entirely from fresh oxide.

In the process of Tessié du Motay certain agglutinant materials are employed in preparing the pencils; but these reduce the brilliancy of the light considerably. With care in the management of the pencils the use of agglutinants may be avoided, and though they may be necessary in the case of pencils to be handled by an ordinary peripatetic calcium light manipulator they are not only unnecessary in the hands of a lecturer; but, are also detrimental exactly in the proportion in which they reduce the brilliancy of the light.

If the zirconium oxide is free from silica there is no evidence of fusion on the extremity of the pencil, though it may have been submitted to the action of the flame for a full hour. If on the contrary silica is present the spot on which the flame impinges becomes glazed, giving evidence of fusion, and the brilliancy of the light decreases greatly. The pencils made from the zirconia prepared in the manner related above have been tested alongside of those made from zirconia prepared by Merck, which is stated to be pure, and is sold at the rate of one dollar per gram. Whatever the process may be that is used in its preparation it does not give a product as free from iron and silica as the one which I have described, nor does it possess the same illuminating power.

June 22d, 1877.

ART. XXX.—*Mineralogical Notes.* No. V. *On the occurrence of Garnets with the Trap of New Haven, Connecticut;* by by EDWARD S. DANA.

GARNETS have been recently discovered in connection with the New Haven trap rocks, at two distinct localities; and their method of occurrence presents some points of considerable interest.

These "trap rocks," as they are commonly called, belong to the system of dikes of igneous rocks which characterize the Mesozoic sandstone areas of the Atlantic border. Mr. G. W. Hawes has given these rocks a thorough chemical examination,* and has shown that they have all essentially the same composition, being for the most part true dolerites, but including also the hydrous, chloritic variety called diabase. I take the liberty of quoting here Mr. Hawes's analysis of the trap from West Rock, which, as he states, is "the typical rock of this region." Specific gravity 3·03.

Silica	51·78
Alumina	14·20
Iron sesquioxide	3·59
Iron protoxide	8·25
Manganese protoxide	0·44
Lime	10·70
Magnesia	7·63
Soda	2·14
Potash	0·39
Phosphorus pentoxide	0·14
Ignition	0·63
	99·89

The writer has made a microscopic examination,† by means of thin sections, of this series of rocks, including, among many others, specimens from West Rock (see the analysis above) and also from the two localities where the garnets have been found, viz: East Rock and Mill Rock. These three points, it should be stated, are within four miles of each other, all lying just outside of the limits of the city of New Haven. It was found that the specimens from the localities named were identical in mineralogical character, and that they were all quite free from any alteration. The mineralogical constituents are as follows: A triclinic feldspar which Mr. Hawes has shown chemically to be labradorite, pyroxene, and magnetite, also more or less chrysolite, and a little apatite in minute acicular crystals.

* This Journal, III, ix, 185, March, 1875.
† This Journal, III, viii, 390.

Garnets from East Rock.

At the East Rock locality the trap is very distinctly columnar, and the garnets occur on the vertical surfaces of the columns where they have been exposed in the process of quarrying. The spot at which they are found is in the body of the dike, far away from the line of contact with the sandstone; they are scattered here quite freely over a considerable surface; a careful search for them, however, along the extended front of the Rock, failed to reveal any other locality.

The associated minerals are: Magnetite, apatite, pyroxene now altered to chlorite, calcite, and also in traces chalcopyrite and sphalerite.

The garnets themselves are uniformly crystallized in rhombic dodecahedrons, with the edges truncated by the planes 2–2. Isolated crystals, however, are rare; more commonly they are grouped together in nearly parallel positions in very pretty little rosettes. These groups are scattered over the exposed surface of the rock, and are quite characteristic of the locality. Still, again, the crystals are crowded together, without any regularity of position, into crusts of some little thickness.

The color of the garnets is generally dark-brown to jet-black, though occasionally they are yellowish-brown. Their luster is very brilliant, and in general they are entirely free from alteration. An analysis of the garnets proved, what indeed was suggested by their appearance, that they belonged to the variety *melanite*, or a calcium-iron garnet having the formula $Ca_3FeSi_3O_{12}$. The material analyzed was taken from the crystalline crusts which have been mentioned. It was selected with care to ensure freedom from the rock, and still more from the apatite crystals, which, as remarked below, were intimately associated with the garnet. The specific gravity was 3·740.

The mean of two analyses gave:

Silica	35·09
Iron sesquioxide (with Al_2O_3 *trace*)	29·15
Iron protoxide	2·49
Manganese protoxide	0·36
Lime	32·80
Magnesia	0·24
Ignition	0·35
	100·48

It has been recently shown by Knop* that the melanite crystals from several localities in the Kaiserstuhlgebirge and also from Frascati contain from three to seven per cent of titanic acid. In view of this fact special tests were made for titanic acid in the progress of the analysis; they served, however, only

* A. Knop, Zeitschrift für Krystallographie, i, 58, 1877.

to prove its absence. The magnetite was also tested qualitatively for titanic acid, but none was discovered.

The associated minerals deserve also a few words of description. The *magnetite* stands first in order of abundance. It appears in the form of brilliant octahedrons, scattered sometimes thickly, sometimes sparsely, over the surface of the rock; it uniformly underlies the garnet where they occur together. The octahedrons of magnetite are sometimes unmodified, but generally the solid angles are replaced with the planes of the form 3-3, and the edges beveled with those of the form 2-2; an *m-n* form is also common, but with planes so rounded as not to admit of determination. The development of the last form occasionally produces irregular bullet-shaped crystals. The octahedral faces are brilliant, the others dull.

The *pyroxene* occurs in minute dark-green crystals, destitute of luster; they are crowded together on the surface of the rock. These crystals are strictly pseudomorphs after pyroxene, for though having unquestionably its form, they are so soft as to be easily cut with a knife, and in the powder have all the appearance of chlorite.

The *apatite* occurs in very minute prismatic crystals of a yellowish-green color. They are most common on and among the crystals of pyroxene. They are more numerous, however, than would appear at first glance, since a careful examination shows that they interpenetrate the garnet crystals in great numbers. The crusts of garnet particularly, which are apparently perfectly homogeneous, are found when broken up to be penetrated in every direction with these minute apatite needles. In this respect the garnets resemble those of the Kaiserstuhl described by Knop.

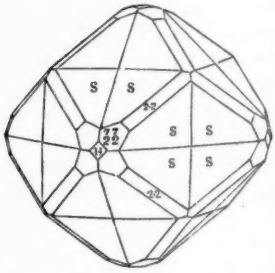
Finally, the *calcite* is found in crusts, and in rhombohedral crystals, covering the other minerals and also the surface of the rock itself. This calcite is very common not only at the point to which the garnets and their associates are confined, but also at many other places, so that it may not have any essential paragenetic relation to them.

All the above minerals are here true secondary products deposited on the columnar surface of the trap, and probably in the following order: magnetite, pyroxene, apatite, garnet, calcite. It will be noticed too, that, of the species which have been mentioned, the magnetite, pyroxene and apatite, are all original constituents of the rock itself, so that it can hardly be questioned that it has furnished immediately the material out of which these later minerals have been formed. The other essential ingredient of the rock, the triclinic feldspar, must have furnished the lime to the garnet and probably to the calcite; the excess of silica above that needed by the garnet, and also the alkalies have disappeared entirely.

Garnets from Mill Rock.

The other garnet locality is at the west end of Mill Rock. In appearance and in method of occurrence the garnets here found are a decided contrast to those that have been just described. They occur on the line of contact between the trap and the adjoining sandstone, and probably owe their origin to the metamorphic action of the heat of the erupted rock. They are found best in seams and little cavities in the trap, where they are implanted as isolated crystals upon an earlier deposit of quartz crystals. Occasional garnets of indistinct crystalline form but presumably of similar origin occur on the surfaces of the sandstone adjoining; scales of hematite produced by metamorphic action are common on the same surfaces.

The garnets in the trap only are distinctly crystallized; the crystals are highly complex and interesting. They appear at first sight to be dodecahedrons, but further examination shows that each dodecahedral plane is replaced by the four planes of a very obtuse hexoctahedron, having the symbol $64\,\frac{6}{6}\frac{4}{3}$; the other forms occurring with this are: 2-2, $\frac{7}{2}$-$\frac{7}{3}$, and *H*. The adjoining figure shows the habit of the crystals. The following angles were measured to determine these forms.



For $\frac{7}{2}\frac{7}{2} \wedge \frac{7}{2}\frac{7}{2}$ (over *H*) $=136°\ 15'$, required $135°\ 59'\ 48''$.
" " " adjacent (edge B)$=149°16'$, required $149°\ 16'\ 38''$.

For $64\text{-}\frac{6}{6}\frac{4}{3}$ edge B $=178°\ 15'$, required $178°\ 5'$.
" " " C $=178°\ 56'$, " $179°\ 6'$.

Of the above enumerated forms, the basal plane (*H*) is quite rare with this species, the tetragonal tris-octahedron $\frac{7}{2}$-$\frac{7}{3}$ is new, though it has been observed on fluorite, and also by Klein (as a hemihedral form) on sphalerite; and the hexoctahedron $64\text{-}\frac{6}{6}\frac{4}{3}$ has been observed only on the *topazolite* from Piedmont (Quenstedt), though the related form $i\text{-}\frac{6}{6}\frac{4}{3}$ was found by Websky on the transparent garnets of Jordansmühl, Silesia.

The Mill Rock garnets have a wine-yellow color, and a brilliant luster. The material available was much too scanty to admit of any chemical examination, but in view of their similarity of form and color, they may safely be referred to the variety *topazolite*.

In addition to the crystallized quartz upon which the garnets are implanted, the only other associated mineral is one occurring very sparingly in silky hair-like fibres. It was impossible to obtain enough for even a blowpipe examination, so that its character remains undetermined.

ART. XXXI.—*A description of the Rochester, Warrenton, and Cynthiana Meteoric Stones, which fell respectively December 21st, 1876, January 3d, 1877, and January 23d, 1877, with some remarks on the previous falls of Meteorites in the same regions;* by J. LAWRENCE SMITH, Louisville, Kentucky.

A SHORT notice of the three meteorites which form the subject of this communication, was published by me shortly after their fall, the detailed account of their flight and fall having been deferred until I could make a more thorough examination. This I am now able to do, as there have been sent to me the entire stone that fell near Cynthiana, and a large portion of the fragments which have been saved of the other two.

The points of interest in connection with these three meteorites are as follows: *First*, they fell within a period of thirty-two days, and within a circumscribed territory of about two degrees of latitude and six degrees of longitude. *Secondly*, they differ from each other in their structural characteristics, and each has some peculiarity distinguishing it from the ordinary type of meteoric stones. *Thirdly*, they fell within a belt of territory, which I shall show has been the lodging ground of all the meteoric masses that have been observed to fall and have been collected in the United States during the past eighteen years, with the exception of about one kilogram.

1. *Rochester (Indiana) Meteorite.*

The passage of this meteorite through the earth's atmosphere has left but a small souvenir of its visit. It was well observed at Bloomington, Indiana, lat. 39° 12′, long. 36° 32′, by the distinguished astronomer Professor Kirkwood, who communicated to me at the time his observations; and he has subsequently given them more in detail to the American Philosophical Society, with the observations he had collected from others. I will therefore simply give a summary of the phenomena attendant upon its flight before describing the chemical and mineralogical characteristics of the stone which fell.

The bolide made its appearance about nine o'clock P. M., December 21, 1876, and was of extraordinary magnificence. It passed eastward over the States of Kansas, Missouri, Illinois, Indiana, Ohio, and parts of Pennsylvania and New York. Although no observations were made in the two last mentioned States, still Professor Kirkwood is doubtless correct in defining this as its course. At Bloomington its elevation was fifteen degrees. According to the calculation, the length of its observed track was from 1,000 to 1,100 miles, one of the longest on rec-

ord. Its height is supposed to have been thirty-eight miles above the place where the small fragment fell from it.

In various parts of its track, it threw off fragments, accompanied with the usual rumbling noise and commotion in the atmosphere common to the flight of these bodies. When crossing Indiana, the main body was followed by a train of smaller bolides, many of them of the apparent size of Venus or Jupiter. Its velocity in reference to the earth's surface appeared to be from eight to twelve miles per second. The pyrotechnic display is said to have been transcendently beautiful, hardly equalled or surpassed by any previous occurrence of the kind. The cause of this brilliancy lay in the physical structure of the body, which will be detailed farther on.

The fragment which fell.—The only fragment of this bolide known to have fallen was one found on the farm of Mr. Morris, three miles northwest of Rochester, Indiana, lat. 41°, long. 86°. This farmer heard the explosion, and shortly afterward noticed a body strike the ground not far from him. There were six inches of snow upon the ground, and, on the following morning he found the stone, which had rebounded to a short distance from the place where it first fell, it not having penetrated the ground. The entire stone did not weigh four hundred grams, and as we have not heard of the fall of any other mass, it is reasonable to suppose that it was dissipated into very minute fragments and dust, as in the case of the Hessle stones and other similar falls.

The manner in which the molten matter of the exterior of many of these meteorites is swept over their surfaces, in shining streaks, covering freshly broken surfaces, show clearly that this disintegration is constantly and rapidly going on in these bodies during their passage through the air. I have in my collection many fine examples illustrating this fact.

Professor Kirkwood is of the opinion that this bolide never passed out of our atmosphere, which is in accord with my general view on this subject, viz: that a bolide rarely, if ever, gets entangled in our atmosphere without being entirely reduced to fragments or powder.

The stone has been broken up into many small fragments, of which I have fortunately secured a good portion. Others have been lost and a few have found their way into collections. With the exception of the largest specimen in my collection, weighing ninety-five grams, hardly any other fragment weighs over thirty grams. It is important to treasure these specimens, small as they are, for it is a remarkable stone of its type. It is of the pisolitic variety, very friable, of a gray color, easily crushed under the fingers into light powder (some of it to fine dust), and to small globules, some of them *perfectly spherical*, of which I

have specimens two millimeters in diameter. It resembles more closely the Aussun stone than any other I know of, although much more friable. This peculiar structure, so often seen in many parts of meteoric stones, has recently attracted much attention, Professor Tschermak, of Vienna, having recently published an interesting paper on the subject.*

The specific gravity of the stone, taken with several average specimens, is 3·55. There is nothing peculiar about the coating on the specimens I have examined; it is of a dull black and quite rough.

Chemical examination.—The stony part of the meteorite separated almost perfectly from the metallic part still contained a notable portion of troilite that could not be separated mechanically. The amount of sulphur found in that part of the meteorite indicated the amount of troilite present, viz: 3·31.

The stony material, when treated with chlorhydric acid over a water bath, affords soluble part 47·80 per cent, insoluble 52·20 per cent, and is constituted as follows:

	Soluble part, per cent.	Insoluble part, per cent.
Silica	34·55	57·81
Iron protoxide	27·75	11·04
Alumina	trace	·23
Lime	trace	5·31
Magnesia	36·38	24·97
Chromium oxide		·10
Soda	·46	·84
	99·14	100·30

I separated some of the globules perfectly free from the intervening matrix, which is easily done by rubbing a piece of the stone between the fingers. Very minute specks of iron could be distinguished on them, and when pulverized and treated with chlorhydric acid, they gave about the same result as the matrix, viz: soluble, 46·80 per cent; insoluble, 53·20 per cent; and the magnesia in the soluble part was 34·48 per cent, showing clearly that they were merely concretions of the matrix of the stone.

The nickeliferous iron, which was separated mechanically, is composed of:

Iron	94·49
Nickel	4·12
Cobalt	·51
	99·12

The quantity of iron was too small for an examination of the other constituents, as phosphorus and copper, but they were no doubt both present.

* Sitzungsb. Akademie der Wissenschaften, vol. lxxi, p. 661.—Wien.

Mineral constituents of the Stone.—Careful examination under the microscope of the broken surface, as well as of a section rubbed down very thin, show the stone to be composed of the unisilicates and bisilicates usually found in these bodies, mixed with nickeliferous iron and troilite; nothing like anorthite is distinguishable. The first two minerals constitute the bulk of the stone, and there is possibly more than one variety of each of these minerals present. The nickeliferous iron is quite abundant, although Professor Shepard states that from a casual observation he estimates it at one per cent; by the careful method adopted for separating it, I find in two average specimens over ten per cent. The particles of iron are very bright and lustrous, looking as if they were covered with plumbago, although there is no evidence of the presence of the latter mineral. The troilite is not detected so readily by the eye as it is by chlorhydric acid. One of the spherules was rubbed down to a thin section and examined by polarized light; and in this way it was found to contain both classes of silicates referred to, a fact, as already stated, sustained by chemical examination. I consider the mineral constituents of the Rochester stone to be about as follows:

Bronzite and pyroxene minerals	46·00
Olivine minerals	41·00
Nickeliferous iron	10·00
Troilite	3·00
Chrome iron	·15

2. *Warrenton (Missouri) Meteorite.*

About sunrise, on the 3d of January, 1877, five miles from Warrenton in the State of Missouri, lat. 38° 50′, long. 91° 10′, a sound was heard by certain observers similar to the whistle of a distant locomotive; or, as stated by others, like the passage of a cannon ball through the air. The sound came from the northwest, and became louder and louder to four observers near Warrenton. On looking up they saw an object falling, which struck a tree, breaking off the limbs, and then coming to the ground with a crash. The observers were fifty or sixty meters distant from the spot where it fell. On approaching the place they saw a mass of stone broken into a number of pieces. From the fragments they suppose it to have been originally of a conical form, and about eighteen inches in length. The snow was melted, and the frozen ground thawed near where it fell, but the pieces, although warm, were easily handled. The weight was estimated to have been about one hundred pounds; but, whether this estimate be correct or not, only about ten or fifteen pounds of fragments have been preserved, a good portion of which is in my possession, mostly in small fragments;

some specimens are in the cabinet of Yale College, and others scattered about among the inhabitants of the country where it fell.

As regards its temperature at the time of falling I would say that I have a specimen, which gives as it were a satisfactory record that it was not very hot when it struck the tree, for a portion of the fibers of one of the branches is adhering to the surface entangled in the rough crust of the stone, and these delicate fibers show not the slightest signs of having been heated. A fact to be noted in connection with the fall of this meteorite is that no explosion was heard, or any luminous phenomena produced, by its passage through the air after it was first noticed; this may be in part due to the fact that the fall happened at sunrise; but it was no doubt a meteorite well spent in its rapid motion through the atmosphere, and dropped quietly like an exhausted bird in its flight. Its direction, so far as made out, was from northwest to southeast.

Aspect of the Stone.—Studied by the various fragments that are under my observation, it differs in a marked degree, although pisolitic, from the one just described, and which fell only a few days previously. It has its own points of peculiar interest, and is not like any meteorite that I am familiar with, except the Ornans meteorite, which fell July 11th, 1868; and this it resembles closely in every particular, as may be seen by comparing my results with those of Pisani (Comptes Rendus Acad. Sci., 1868, vol. ii, p. 663), although his method of recording the analytical results is different from mine, and the specific gravity, as made out by him, is higher than mine, which is not singular in different specimens of these porous bodies. Its crust is dull black, and quite thick; in many places, of several centimeters square, from two and one half to three and one half millimeters thick (the thickest I have ever seen), where the crust is a rough scoria that sometimes terminates abruptly on a smooth portion of the crust, and is doubtless produced by the melted matter on the surface being forced backward and opposite to the direction of the flight of the stone, being swept off one portion of the surface, and leaving this part smooth, and piled up behind it, in the form of a surface of scoria.

The interior of the stone has a very dark uniform ash color, and is soft and easily crushed; the latter fact accounts for its having broken into fragments as it struck the ground. Its specific gravity is 3·47, and the amount of metallic matter contained in it is small.

Chemical composition.—The stone pulverized and freed from metallic particles gave on analysis an amount of sulphur equal to 3·51 per cent of troilite; the amount of nickeliferous iron was small, being equal to 2·01 per cent. The stony minerals treated with chlorhydric acid gave—

Soluble in acid ..... 80·40 per cent.
Insoluble in acid ..... 19·60 per cent.

composed as follows:

	Soluble.	Insoluble.
Silica	33·02	56·90
Iron protoxide	37·57	10·20
Alumina	0·12	·20
Lime	trace	7·62
Magnesia	28·41	22·41
Soda	·07	1·00
Nickel oxide	1·54	
Cobalt oxide	·31	
Chromium oxide		·33
	101·04	97·66

I obtained chrome oxide thirty-three per cent, indicating 0·50 of chrome iron, if the chrome be present in that form. There is no way, however, by which I can decide this question, although it is probable, since the chrome is in the insoluble part; the oxide of nickel, with the exception of perhaps a minute portion, belongs to the composition of the soluble silicates.

The nickeliferous iron contained in this stone is very small in quantity. This on analysis gave

Iron	88·51
Nickel	10·21
Cobalt	·60
	99·32

Mineral constituents of the Warrenton Meteorite.—A microscopic examination did not give me any clear indications, for it is not possible to prepare a good section for observation. Its chemical examination, however, shows the usual uni- and bi-silicates, of the olivine and bronzite and pyroxenic types. The most marked feature is the preponderance of the olivine minerals, constituting four-fifths of the mass. The proportion of the mineral constituents is about as follows:

Olivine minerals	76·00
Bronzite and pyroxenic minerals	18·00
Nickeliferous iron	2·00
Troilite	3·50
Chrome iron	·50

3. *Cynthiana (Kentucky) Meteorite.*

I have called this the Cynthiana stone, although it fell nine miles from that place, in Harrison county, Cynthiana being the nearest important point to the place where it fell.*

* I will take occasion just here to correct an error that I have seen in several catalogues, among them those of Vienna, the British Museum, and the Garden of Plants. These catalogues designate the meteoric fall described by me in 1858, as that of Harrison county, Kentucky: it should read Harrison county, *Indiana*.

At four o'clock P. M., on the 23d of January, 1877, a brilliant bolide was seen traversing Monroe county, Indiana, in a southeasterly direction, about thirty-five degrees above the horizon. The same bolide was observed by a number of persons in Decatur county, of the same State, lat. 39° 27′, long. 85° 28′, and it disappeared just as it seemed to touch the earth, apparently not more than a quarter of a mile distant. As will be seen, it fell about sixty miles distant from these places. It seemed to fall almost perpendicularly toward the earth's surface. I cannot learn that it was seen by any one in the State of Ohio, but suppose that it was. In the State of Kentucky it was seen over a considerable territory. The phenomena culminated in the usual noises heard in the heavens accompanying the approach of these bodies, and much consternation was produced among the inhabitants of the surrounding country. Fortunately one of the observers, an intelligent farmer (Mr. Cragmyle), heard a solid body strike the ground; he walked immediately to the spot, and dug the stone from a depth of thirteen inches, to which extent it had penetrated the ground. A few days after its fall and before it had become generally known, Professor Kirkwood wrote me a letter, stating what observations had been made in Indiana, and telling me to look out for a meteoric fall somewhere about the region where the stone did fall. I had, however, made the observations and secured the meteorite, before his letter arrived, but the stone had not yet been forwarded to me.

Character of the Stone.—It is wedge-shaped, with one portion of it very extensively and regularly pitted, while the rest is comparatively smooth. The crust is dull black, and, as it reached me, it was as perfect as when it fell. There was a fresh broken spot of two or three square centimeters, which, to a casual observer, would appear to have been made after the fall; but upon close examination, I saw that it had been made prior to the fall, and before the melted matter of the surface had entirely cooled, for a few small specks of this matter have been sprinkled on this broken surface, to which it firmly adheres, and the molten matter is running over one border of it. This could not have arisen from any fusion of that surface, which is too fresh and unaltered to have been heated to any high degree. The fracture was produced by the same cause that produced the pitting.*

The weight of the stone is six kilograms. It is of the harder brecciated variety, and when broken presents a mottled surface, identical with that of the Parnallee stone, which it resembles also in every other particular, the very pale yellow round spots,

* This is clearly and fully set forth by Professor Maskelyne, in the Phil. Mag., for August, 1876.

sometimes five or six millimeters in diameter, are disseminated through the two alike; and so with the triolite, the globular structure in some parts, and a few specks of a black siliceous mineral; and, by a singular coincidence, the specific gravity of the part I tested is identical with that as made out by Maskelyne, viz: 3·41. Under the microscope it presents the appearance described by the same author.

Chemical examination.—The stony material freed from metallic iron, consisted of—

Matter soluble in chlorhydric acid	56·50
Matter insoluble in chlorhydric acid	43·50

Some of the soluble part was composed of troilite, which I could not separate mechanically, but is deducted in the following analysis:

	Soluble part.	Insoluble part.
Silica	33·65	57·60
Iron protoxide	30·83	11·42
Alumina	·11	·43
Lime	trace	5·70
Magnesia	34·61	23·97
Chromium oxide		·38
Soda		1·24
	99·20	100·74

The portions examined contained nickeliferous iron 5·93 per cent, consisting of:

Iron	90·64
Nickel	8·35
Cobalt	·73
	99·72

Mineral constituents of the Cynthiana Stone.—The minerals in this stone are quite easily distinguished by the eye, but are very much more conspicuous under a moderate magnifying power, especially the round and distinct concretions of a light yellow bronzite. The troilite and metallic specks and filaments are also easily seen.

No attempt was made to separate the stony minerals in sufficient quantity for analysis; quantitative tests were made to distinguish their character. From the chemical examination previously made I deduce the following as about the proportion of the mineral constituents:

Olivine minerals	50·00
Bronzite and pyroxenic minerals	30·00
Nickeliferous iron	6·00
Troilite	5·50
Chrome iron	·52

There were no distinct crystals of minerals visible either to the unaided eye or with a lens.

4. *Remarks on the region where these meteorites fell.*

In the study of the three aerolites just described it is interesting to note the relation of the region where they fell to that of previous falls of recent date.

During a period of less than eighteen years there have been twelve falls of meteoric stones in the United States, of which specimens have been collected. All of these, with one or two exceptions, I have described in detail, and furnished specimens to various cabinets in this country and in Europe.

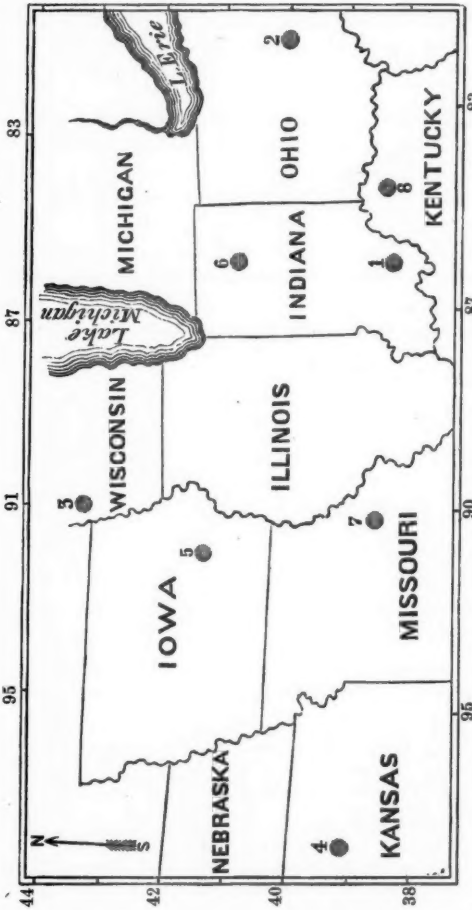
In grouping together these twelve falls and estimating the amount of meteoric matter accompanying them, I have been struck with the singular fact that eight of them, with over one thousand kilograms of matter, have occurred over the prairie regions of the West, not far from my home; and the extreme limits of these falls is within a region not exceeding one-eighth of the surface of the United States, east of the Rocky Mountains. It may be supposed that one reason for this may be that this region is more thickly populated than others, and consequently that there are more observers. This however is not the case, for the population is not much above the average of the country.

I have made a map of the region (see next page) where these eight falls occurred, which shows at a glance their relative positions. The accompanying table gives a few comparative details in relation to each of them.

No.	Time of Fall.	Place of Fall.	Lat.	Long.	Estimated Weight of Fall.
1	28th March, 1859	Harrison Co., Ind.	38° 20′	86° 10′	1· kilo.
2	1st May, 1860	Guernsey Co. (Concord), O.	40	81 30	500· "
3	25th March, 1865	Claywater (Vernon Co.) Wis.	43 30	91	3· "
4	Not known, 1874	Waconda, Kansas,	39 20	98 10	40· "
5	12th Feb., 1875	Iowa Co., Iowa,	41 40	92	500· "
6	21st Dec., 1876	Rochester, Indiana,	41	86	·40 "
7	3d Jan., 1877	Warrenton, Missouri,	38 50	91 10	10· "
8	23d Jan., 1877	Cynthiana, Ky.	38 20	84 20	6· "
				Total,	1060·40 kilos.

There have been four other falls in the United States during the same period; but the aggregate weight of them is less than two kilograms. They occurred respectively. Nov. 28th, 1868, lat. 34° 30′, long. 87°; Dec. 9th, 1868, lat. 34° 30′, long. 87° 50′; Oct. 6th, 1869, lat. 32° 10′, long. 85°; May 21st, 1871, lat. 44° 30′, long. 69° 10′.

Again: in this region more bolides have recently been observed than in any other. Professor Kirkwood has described,



as seen by him and others, eight from July, 1876, to February, 1877, the stones from three of them are those described in this paper, the others left no evidence of their passage. By personal observation I have noted, in the last two or three years, three splendid bolides, that were seen to burst in the sky, but of which no fragments were found; these I have described, and still others have been described to me by several observers. It is a still more striking circumstance, that, in the past sixty

years, there have been twenty well noted falls of meteoric stones; and of these just one half have fallen within the region mapped by me as including the eight falls of the past eighteen years; and the weight representing them is nearly twelve hundred kilograms—an amount twenty times greater than that of the other ten falls scattered over various regions.

I have mentioned this singular fact not that it has any cosmical significance, but simply as a part of the record I keep of my observations and study of these curious links between heaven and earth. Before very long I hope to put together my more recent speculative studies in regard to these bodies.

ART. XXXII.—*Notice of a new genus of Annelids from the Lower Silurian;* by GEO. BIRD GRINNELL.

THE Museum of Yale College has recently received, from the rocks of the Cincinnati group, a series of fossils which are of unusual interest. The remains are shining black in color, and present a striking contrast to the associated fossils, Trilobites, Brachiopods, Crinoids, etc., which have assumed the color and constitution of the matrix. An examination of these black remains shows that they are the hard chitinous parts of Annelids.

While the presence of animals of this group in the Lower Silurian has been inferred from their "trails" and impressions in the rocks, no portions of their bodies have as yet been found preserved in the deposits of this age. The remains which first suggest themselves for comparison with these specimens are the Conodonts of Pander. Through the kindness of Professor Marsh, the writer has been enabled to examine a number of the original specimens of these fossils, collected by Pander himself near St. Petersburg; and a comparison makes it clear that they are quite unlike the remains referred to. They are widely different in color and form from the material under observation, while chemical tests show that their composition is by no means similar.

These Cincinnati fossils include a large number of specimens, and, as might be expected, there is a wide variation in their form. So little is at present known in regard to the jaws of Annelids, that any general conclusions drawn from the material at the command of the writer would be premature; and for the same reason it would be unwise to distinguish by a name each of the many forms which appear. Further study will doubt-

less furnish data for a more extended description, with numerous illustrations, which it is hoped will soon be completed.

1. 2.

× 5. × 10.

Nereidavus varians, gen. et sp. nov.

The jaw selected as a type for the genus (fig. 1), is one of the largest and most perfectly preserved of those at hand. It is dark brown, with a coppery luster in some places, this coloring being due to the weathered condition of the specimen. It is hollow at the base and throughout the greater part of its length, and so strikingly resembles the jaw of the common *Nereis pelagica* Linn. of the Atlantic coast, as to render their near affinity almost certain. The denticulations, or teeth, are eight in number, but were probably more numerous originally, since the posterior portion of the specimen is wanting. The anterior tooth, which is the largest, is somewhat twisted outward, not lying in the same plane with its fellows. The length of the specimen is 5·6 mm., the depth beneath the fourth tooth 1·4 mm.

A second very perfect specimen, which may possibly belong with the jaw above referred to, is represented in fig. 2. It contains eighteen teeth, the anterior one quite long and stout, the next five mere slight protuberances, and only to be seen under the microscope, while the remaining teeth are sharp and strong. The length of the exposed portion of this individual is 2·8 mm.; depth under the first of the strong teeth, the seventh in the series, ·22 mm. Since the base of this specimen is buried in the rock and cannot be seen, it is not altogether certain what it is. It bears some resemblance to one of the setæ of *Nereis Dumerilii*, Aud. and M. Ed., figured by Ehlers in his work entitled Die Borstenwürmer, pl. XX, fig. 31.

The specimens under consideration were collected by Professor A. G. Wetherby, near Cincinnati, Ohio. Through the energy and courtesy of this naturalist, a large suite of specimens has been secured and forwarded to New Haven, and to him the writer would express his grateful acknowledgments.

Yale College Museum, New Haven, Conn., July 28th, 1877.

SCIENTIFIC INTELLIGENCE.

I. PHYSICS.

1. *The Radiometer.*—A large number of papers on this subject have appeared during the past few months. Several of these have been published in Poggendorff's Annalen, and of the rest, excellent abstracts are given in the "Beiblätter" to that journal. They give evidence of a very great amount of ingenuity expended in devising experiments to test the theory of this very remarkable instrument, and they show how easily experimental evidence may be misinterpreted in support of an assumed theory when the phenomena in question are liable to be modified by many adventitious circumstances. Five theories of the radiometer have found prominent and weighty advocates. The first regards the motion of the instrument as a *direct* effect of radiation. The second refers it to electrical action. The third to convection currents. The fourth to the emission of material particles from the vanes or the walls of the instrument. The last finds in the apparatus simply a new heat engine, and sees in the motion a simple result of the difference of temperature of the parts, wholly in accordance with the modern mechanical theory of heat.

When this motion was first discovered it seemed to be a direct mechanical effect of radiation, and there were not wanting ingenious speculations to show how the force exerted by the waves of the luminiferous ether might be resolved so as to produce such an effect. It is to be remarked, however, that Mr. Crookes, to whom we owe the discovery, did not indulge in such speculations, and, as he says, aimed to keep himself unbiased by any theory while he accumulated the facts upon which a satisfactory explanation might be based. But the very name *radiometer* implied, and the whole tenor of his published papers have certainly justified, the common opinion that, until very recently, he regarded the phenomena—he had so admirably developed—as a *direct effect* of radiation, and not, as he now thinks, a secondary result depending on differences of temperature, which may be produced by radiation or by other means. Hence, several experimenters have labored to show that in the motion of the little wheel of the radiometer the reaction was exerted not against anything independent of the instrument, but against the enclosing walls of glass. The early experiments of Mr. Schuster* on this point were very convincing. He hung the whole instrument by a delicate bifilar suspension, and found that while the vanes were revolving under the action of a beam from an oxyhydrogen lamp, the glass bulb also turned slightly in the opposite direction. Soon after M. Salet† constructed a very ingenious apparatus in which this reaction was made to turn a mica disk; and very recently, M.M. Bertin et

* Philosophical Magazine, Nov., 1876.
† Comptes Rendus, Nov. 20, 1876.

Garbe* have published an interesting paper, in which they show by careful measurements that the reaction of the glass bulb fully accounts for the motion of the wheel; and their investigation may be regarded as finally disposing of the radiation theory, by proving that the motion of the wheel of the radiometer is wholly caused by forces which act within the glass bulb.

The electrical theory has never had many supporters. It is, however, defended in two recent articles by J. Delsaulx† and W. de Fonvielle.† In opposition it is urged that no distribution of statical electricity could maintain a constant motion,‡ and further, Mr. Crookes§ cites an experiment of Mr. Cromwell F. Varley, with an apparatus so arranged that the electrical condition could be tested with a delicate electroscope; when not the slightest trace of electrical excitement could be detected, although the motion of the wheel was regularly maintained.

The convection theory has been recently advocated by F. Neesen,‖ who describes a number of experiments which he thinks indicate that the wheel of the radiometer is moved by the gas currents occasioned by the rising or falling of the residual air particles as they are warmed or cooled, at the surfaces of the vanes or of the enclosing glass walls. But the effects he obtains by placing similar wheels unsymmetrically under the receiver of a mercury pump, do not, as it seems to us, necessitate his explanation, and moreover the distinction between the effect of convection currents and the peculiar motion of the radiometer is strikingly marked in many experiments which have been elsewhere described, the one passing into the other at a certain degree of exhaustion.¶

The emission or evaporation theory appears to have originated with Mr. Osborne Reynolds. It was later maintained by Govi,** and recently it has formed the subject of an extended article—in three parts—by F. Zöllner.†† This theory refers the motion to an alternate emission and absorption of material particles—determined by variations of temperature—at the several surfaces, between which the moving forces in the radiometer are exerted. The particles thus emitted may be either those of aeriform substances adhering to or occluded by the solid materials of which the instrument is made—as Reynolds supposed—or it may be, as Zöllner suggests, that these solids themselves *evaporate* slowly into the vaccuous space. Leaving, however, such questions in abeyance—as these physicists prefer,—there is no doubt that the general order of the phenomena might be explained if the assumptions which the emission theory requires could be accepted; but on the other hand, the phenomena which Zöllner adduces in support of his view, may be,—for the most part at least—fully as well explained by the more general mechanical theory of heat. Zöll-

* Annales de Chim. et de Phys., [V] xi, 45, Mai, 1877.
† Beiblätter, i, 170. ‡ Beiblätter, i, 329. § Pogg. Ann., clx, 143.
‖ Compare Zöllner, Pogg. Ann., clx, 459. ¶ Proc. Royal Soc., 1874, June 18.
** Pogg. Ann., clx, 154, 296 and 459. †† Comptes Rendus, lxxxiii, 1.

ner endeavors to show* that the mean path of the molecules of the residual gas in the bulb of the radiometer, when it is in the condition of maximum sensitiveness, is not large enough to fulfill the conditions which the mechanical theory requires. On the other side, Crookes† has obtained motion or the reverse, under conditions which certainly appear incompatible with the emission theory. Moreover, the very fact which appears to have been well established by several observers, that, with a certain degree of exhaustion, different for different gases, a point of maximum sensitiveness is reached, and that on further exhaustion the sensitiveness rapidly diminishes, seems to us,—especially when viewed in connection with the experiments just referred to—fatal to the emission theory.

The last theory we have to consider is, as we have said, but a phase of the mechanical theory of heat. The application of the now well known principles of molecular dynamics to the explanation of the new phenomena is said to have been first suggested by Mr. Johnstone Stoney.† Similar views were also very early expressed by Professors Tait and Dewar.‡ More recently they have been adopted by Mr. Crookes,§ and are now very generally accepted by physicists.

According to the mechanical theory of heat, the molecules of any gas which rebound from a surface with a temperature—that is, with a velocity—different from that with which they struck, must cause a recoil, and this must be the general case whenever the temperature of the surface is different from that of the mass of the gas. Unless, however, the density of the gas is exceedingly small, the rebounding molecules almost at once collide with their neighbors, and are immediately driven back against the same surface. Thus the change of temperature merely affects a very thin layer of molecules near the surface, and these are only slowly displaced by convection. In such an atmosphere, the vanes of a radiometer, for example, with the adjacent molecules, are parts of one system, and, by a well known mechanical law, no motion of the system as a whole can be produced by any action between its parts; but when the medium becomes so rare that the mean path of the molecules is comparable with the dimensions of the enclosing vessel, so that some of the molecules, rebounding from the vanes of the radiometer, may even reach the opposite walls, then of course a force is exerted between the opposing surfaces, and the now familiar motion of the wheel is the result. The radiometer is then simply a heat engine in which the action takes place between two surfaces of different temperature, the heater and the cooler of the engine. As such a difference of temperature may be maintained in a great variety of ways, so the apparatus admits of a great number of modifications. Moreover, it is obvious that

* Pogg. Ann., clx, 305. † Beiblätter, i, 167 and 330. ‡ Nature, July 15th, 1875.
§ Philosophical Transactions, vol. clxvi, p. 375, in postscript dated June 17, 1877. See also Mr. Stoney's papers. Phil. Mag., V, i, pp. 177–182, 305–314, (1876).

when, as in most cases, the difference of temperature is the result of radiation, very irregular effects may be produced by the different absorbing or radiating power of the surfaces for the various rays of the spectrum, and also by similar differences in the diathermancy of the glass envelope. It is not surprising then that some of the phenomena which have been met in the course of the numerous investigations already made on this subject, should have been so difficult to trace. There can be no question, however, that the general order of the phenomena is fully explained by this theory. In the postscript just referred to, Mr. Crookes writes, "Twelve months' research, however, has thrown much light upon these actions, and the explanation afforded by the dynamical theory of gases makes, what was a year ago obscure and contradictory, now reasonable and intelligible."

It does, however, still remain to show that the dynamical theory of heat is quantitatively as well as qualitatively confirmed by the new phenomena. The necessary measurements unfortunately present very great experimental difficulties, and the data thus far obtained can only be regarded as rough estimates, and for this reason we do not attach much importance to the criticisms of Zöllner already referred to. Among the results bearing on this question recently obtained, the most interesting are the following.

Of course, according to the theory in question, there would be no motion whatever in an absolute vacuum, and hence, as we have intimated, the molecular pressure on the vanes of a radiometer ought to reach a maximum effect with a certain limited degree of exhaustion. Moreover, as the length of the mean path of a molecule, other things being equal, depends on the molecular weight,—the lightest molecules having the greatest extent of motion under the same conditions,—it also follows that the limit just mentioned should be sooner reached in the residue of a light than in that of a heavier gas. In accordance with these anticipations, Mr. Crookes has found that while with hydrogen the maximum effect is reached at a tension of about 0·0532 millimeters, it is not obtained with oxygen until the tension is reduced to 0·0228 millimeters, or less than one half of the previous value. In an ordinary radiometer, according to the same experimenter, the tension of the residual air is about 0·19 millimeters, but he has succeeded in reducing it to 0·0076 millimeters, and then the velocity of the motion was only one-tenth of the maximum. Still later he states that by heating the bulb to 300° during the exhaustion, he has been able to reduce the tension to one or two millionths of an atmosphere, and that he can most readily secure the condition of greatest sensitiveness by first pushing the exhaustion to the utmost limit of the power of his apparatus,* and then with the aid of a peculiarly constructed cock allowing gas to enter until the proper tension is reached. By

* Crookes has obtained these later results with a new form of the Sprengel pump, contrived by C. H. Gimingham, and an ingenious application of the mercury gauge to measuring low tensions, made by McLeod. Full descriptions of these new forms of apparatus, with figures, will be found in the Beiblätter, i. 175.

using vanes of mica previously rendered anhydrous by ignition and working with hydrogen, he has thus succeeded in constructing a radiometer of such sensibility that it moved under the sole influence of the moon's rays. The results of Finkener on the point of maximum sensibility in different gases confirm those of Crookes, the two series of measurements agreeing as nearly as could be expected, and all these results—with yet others—have been collected in a very interesting paper recently published by M. Bertin.* No one has yet succeeded in pushing the exhaustion so far beyond the point of maximum effect that the radiometer became again insensible to radiation, nor was that to be expected.

It is another consequence of the dynamical theory of gases that a radiometer with a small bulb ought to be more sensitive—under otherwise like conditions—than one with a large bulb, and this also has been fully realized by Mr. Crookes.† Quite recently, Stoney and Moss‡ have published some preliminary results of an investigation, in which they propose to compare the molecular pressure between the "cooler" and "heater" in this new form of heat engine at different distances and with various gas residues, and under varying conditions of tension, temperature, etc. The investigation was begun soon after the publication of Stoney's original communication to the Phil. Mag., March, 1876, and is not yet completed. They give a description of their apparatus, and they call the reaction exerted between the cooler and heater in the radiometer and all similar instruments, "Crookes' Force." We must refer to their paper for details which appear to authorize the conclusion that in a residue of hydrogen having a tension of five millimeters, the molecular pressure, or "Crookes' Force," is sensible at a distance of at least ten millimeters.

Again, although the molecular pressure we are considering must in general conform to the well known laws of hydrostatics, like the tension of the atmosphere, yet the mechanical theory of gases would lead us to anticipate certain striking differences of effect resulting from the great amplitude of the molecular motion in an extremely rarified medium. Thus the tension of the atmosphere does not move the vanes of an anemometer; but a wind does. And in a somewhat similar way—when the wheel of a radiometer is made like that of the anemometer—the resultant of the recoils due to the acceleration of the rebounding molecules will be greater on the convex than on the concave surface of the cups, although being made of thin metal plate, the temperature of the two surfaces must be essentially the same. Such effects have been studied both by Crookes§ and by Zöllner.‖

It is greatly in favor of the view of the subject last presented that it does not invoke a new agency or exaggerate an old one to explain the new phenomena; but it is merely a new phase of an already well established theory, which, by thus readily marshalling the new phenomena, becomes more firmly established. Indeed, to

* Annales de Chimie et Physique, V, x, 396, Mars, 1877. † Beiblätter, i, 165.
‡ Beiblätter, i, 318, No. 6; also Proc. Roy. Soc., xxv, 553.
§ Beiblätter, i, 169. ‖ Pogg. Ann., clx, 159.

those who accept this theory the radiometer becomes an instrument of the very highest interest, affording as it does, another and very striking manifestation of molecular motion. Moreover, when we shall be able to overcome the experimental difficulties so as to estimate with certainty the force exerted under determinate conditions, we may hope to obtain by its aid a direct measure of absolute molecular magnitudes.

We may be permitted to add to this notice a brief account of a few experiments made with the radiometer at Cambridge in the spring of 1876, soon after the instrument had been received from Europe. We became at once greatly interested in the new phenomena, and with the aid of a skillful glass blower made more than a hundred instruments of different patterns. Our experience led us at once and independently to the theory of its action now generally received; but although we sustained this view in our college lectures, in a communication to the American Academy, and in a popular article in the Boston Daily Advertiser, we did not otherwise publish our results, because we felt that the field had been in a measure preëmpted by the discoverer of the phenomena, who was then investigating the subject, and who, we felt sure, must come at last to the same conclusions which we had reached. Our results can now add nothing to the strength of the theory, which has been since so well worked out by Mr. Crookes, but two of the experiments have never been—so far as we know—described before, and being so simple that they can be easily repeated in any physical cabinet, a description of them, even at this late day, may have an interest for teachers of physics.

We first experimented with a common radiometer having mica vanes blackened on one side, which we placed in a beam of parallel rays from an oxyhydrogen lantern; and having satisfied ourselves—by using an alum cell—that the rays acted chiefly at least through their heating and not their luminous power, we made at once this experiment. We placed an opaque screen near the radiometer so that only the blackened faces should be exposed as the wheel turned the vanes into the beam of light. We then counted with a stop watch the number of seconds which passed during ten revolutions. We then in a similar way exposed only the uncoated faces; when the wheel continued to turn in the *same direction*, although much more slowly than before. Again we counted the revolutions. Lastly we counted the revolutions while the beam shone on both sides of the vanes as usual. We repeated the experiment several times, and were surprised at the remarkable constancy of the results. They were as follows:

	Time of ten revolutions.	Revolutions in same time.
With both faces exposed	8″	319
With lampblack faces alone exposed	11″	232
With mica faces alone exposed	29″	88

and it will be noticed that 88+232 equals very nearly 319. Now any uniform force whatever, acting from without and at once on the two arms of a lever like these vanes, must act differentially and not concurrently, as here. Hence the reaction which causes

the motion must take place between the parts of the instrument itself; or else we are driven to the most improbable alternative that lampblack and mica should have such a remarkable selective power that the impulses, then supposed in some mysterious way to be imparted by the beam of light, could exert a repulsive force at one surface and an attractive force at the other. Were there, however, such an improbable effect, it must be independent of the thickness of the mica vane; while on the other hand, if, as seemed to us most probable, the whole effect depended on the difference of temperature between the lampblack and the mica, and if the light produced an effect on the mica surface only because the mica plate being diathermous to a very considerable extent, the lampblack became heated through the plate more than the plate itself, then it would follow that if we used a thicker mica plate, which would of course absorb more of the heat, we ought to obtain a marked difference of effect. Accordingly we repeated the experiment with an equally sensitive radiometer—which we made for the purpose with comparatively thick vanes; and with this the effect of a similar beam of light on the mica surface was absolutely null, the wheel revolving in the same time whether these faces were protected or not. It was now an obvious step to heat the glass of the bulb independently of the vanes in order to see if under these circumstances we should not obtain a reverse action. This was easily effected both by warming the glass over a lamp and also by placing the bulb tangentially toward the beam from the lantern, so that it heated the glass without striking the vanes of the wheel. We thus easily obtained the now familiar reverse motion, but which was to us a new discovery. We therefore felt ourselves justified in speaking of the radiometer, as we did in the communications referred to, as a heat engine, of which, when moving in the ordinary way, the lampblack surface of the vanes is the "heater" and the inner surface of the glass bulb the "cooler," but in which these conditions could be reversed as just described. And then the parallel with the steam engine, which we drew, suggested the extension of the dynamical theory of gases to include the new phenomena almost in the very words used above. Moreover, while exhausting the large number of radiometers of which we have spoken, we noticed variations in the effects produced, caused by differences in diathermancy between crown and flint glass, and were thus led to realize what an important part this property of matter played in these phenomena. We also observed that the larger the bulb to the greater degree must the exhaustion be pushed in order to obtain equal sensitiveness. We further found that the same sensitiveness could be more readily obtained with a residue of hydrogen than with one of air, and we recognized plainly that there was with each instrument a point of maximum sensitiveness which could not be exceeded. We had also devised an apparatus for measuring the force exerted under determinate conditions, but our experiments were brought to an end by the sudden death of the only skillful glass blower in our neighborhood.

Soon after these experiments, Mr. B. O. Peirce, now assistant in the Physical Laboratory of Harvard College, made the following striking comparison of the relative effects produced by a large variation in the same radiant source on a radiometer and a thermopile. He used a large Bunsen burner provided with an air valve, so that the non-luminous could be at once changed to a luminous flame. He placed the burner midway between the radiometer and the pile which were about one meter apart. The radiometer was protected from the radiation of surrounding objects by a tin case, blackened on the inside, except where a circular aperture admitted the rays of the lamp and where the reflecting surface of the cover set obliquely enabled the observer to count the revolutions of the radiometer wheel. In front of the thermopile was placed an opaque screen, having an aperture of the same size as that of the radiometer case, and also a thin plate of glass to correspond to the glass of the radiometer bulb. Beginning with the non-luminous flame, Mr. Peirce counted the number of turns of the wheel of the radiometer in a minute, and also took the readings of the galvanometer; then, after rendering the flame luminous (by shutting the air valve), the same observations were repeated. A comparison of the similar values gave, of course, the relative radiation of the non-luminous and the luminous flame as measured by the radiometer on the one side and the thermopile on the other.

	Radiometer.	Thermopile.
1.	0·343	0·287
2.	0·309	0·380
3.	0·248	0·283
4.	0·267	0·325
5.	0·277	0·350
6.	0·367	0·250
7.	0·394	0·304
Mean,	0·315	0·311

While, therefore, there was quite a large variation between the several observations, as might be expected with such a variable source as a Bunsen flame, yet the close agreement of the averages showed conclusively that with the radiometer, as with the thermopile, the effect caused by the rays of light must arise solely from the change of temperature thus produced. It will be noticed that—as measured by either instrument—the radiation of the luminous flame produced only about three times the effect obtained from the non-luminous flame; while a photometric comparison made at the same time showed that the illuminating power of the first was at least a thousand times greater than that of the second. Two separate experiments gave 1080 and 1079 times greater respectively.

In this notice we have been able to refer to only a few of the salient points presented in recent articles on the radiometer, and it will of course be understood that our limits prevent us from even alluding to a large number of other very interesting observations bearing on the subject. J. P. C., JR.

Newport, August 3d, 1877.

II. Geology and Mineralogy.

1. *Gravel deposits referred to the Drift, in Boone County, Kentucky.*—Mr. George Sutton states (Proc. Amer. Assoc., 1876, p. 225), that on the highest part of the table-land in Boone County, Kentucky, 450 to 500 feet above high-water mark in the Ohio, there are extensive deposits of gravel, some of which is cemented into a firm conglomerate. Similar accumulations occur at a height of about 100 feet above the same level near the mouth of Wolper Creek, and a bluff of it at this place has a height of 72 feet. It here blends with a stratified terrace formation which extends for six or seven miles along the river and is in some places over a mile in width. The material is unstratified, small pebbles and large angular bowlders being mingled in confusion. Near this part of Kentucky, the Great Miami and the White Water rivers, coming from the north, empty into the Ohio, where the river makes a sudden bend to the southeast, forming an acute western angle of the great North Bend. A line drawn from the valleys of these rivers across this acute angle intersects the drift conglomerate at Wolper Creek. Along this line, behind hills east of Petersburgh, Kentucky, there is an ancient valley of the Ohio, three to four miles long and half a mile broad, cut out of the rocks, which is now above the highest floods of the river. The drift accumulations are attributed to glacier ice coming down the Miami and White Water valleys, and crossing the Ohio valley, carrying drift material for deposition beyond. The author supposes that there may have been ice obstructions in the Ohio below, to have favored the transfer across; but if the glacier was the wide-spread northern glacier, extending across into Kentucky, the obstructions would hardly have been necessary. North of the Ohio the drift occurs nearly opposite Loughery Island, and at the mouth of Hogan Creek, at about the same height as the river-terrace formation in Kentucky. That of Hogan Creek consists of laminated clay and loam with very little gravel, and, as the author remarks, it was evidently formed away from the current of the Ohio River.

2. *Gravel Ridges in the Merrimack valley.*—Mr. G. F. Wright describes the gravel ridges connected with the Quaternary of the Merrimack valley, in the vicinity of Andover and both south and north of that place, in the Proceedings of the Boston Society of Natural History for December, 1876. At Andover there are three such ridges, at a height of 82, 90, and 132 feet above the bed of the river, the highest being most remote from the stream. They are often only wide enough at top for a foot path. The courses of the ridges are more or less tortuous, and they are frequently broken into hills among which are often depressions occupied by water. They consist of sand, gravel and water-worn stones, and stones from a few inches to two feet through, and they are not in all parts stratified. The coarse material is as

likely to abound near the top as at the bottom. The material overlies the "bowlder clay" or "till" of the region. These ridges are part of what are referred to as "Kames" by Mr. W. Upham in a paper noticed on page 156 of this volume. They are regarded by Mr. Wright as depositions directly from the glacier during its dissolution, modified afterward by the water which, especially in the summer months, would have flowed freely, over, beneath and from the foot of the glacier.

3. *On the supposed Fossil Tracks called Protichnites and Climatichnites;* by Professor E. J. CHAPMAN.—The Potsdam sandstone of Beuharnois and Vaudreuil, Canada, near the junction of the St. Lawrence and Ottawa rivers, and the same formation in the vicinity of Perth, Canada, afforded the *Protichnites*, four species of which were made out by Professor Owen. Professor Chapman, of Toronto, concludes, from his examination of them that they are impressions of large fucoids. This view he regards as strengthened by the occurrence of the *Protichnites* at Perth along with the impressions known as *Climatichnites*. The latter have the form of a band five to six inches wide and several feet in length, with transverse series of narrow parallel ridges, an inch and three-quarters apart, which he believes cannot be explained satisfactorily, except on the supposition of their having been the impressions of large fucoids. Professor Chapman therefore suggests a change in the names to *Protichnides* and *Climatichnides.*—*Canadian Journal*, July, 1877.

4. *Glaciers of the Swiss Alps in the Glacial era.*—Mr. A. FAVRE has prepared a chart containing the results of his study of the older glacial phenomena of the Alps. It is on a scale of $\frac{1}{250000}$. He states that the contours of five principal glaciers proceeding severally from the Swiss valleys of the Rhine, the Aar, the Reuss, the Linth and the Rhine, have been distinguished and their limits, as nearly as obtainable, have been laid down. The thickness of the glaciers, as deduced from the erratic blocks along the upper limit was from 1,200 to 1,600 meters. From the distribution of bowlders, the pitch of the upper surface of the ancient glaciers has been ascertained to be about thirty feet in 1,000, in the narrow valleys, while elsewhere it was more gentle; and in some places the surface was, for 50 kilometers in length, horizontal or nearly so. This state of things gives to the ancient Swiss glaciers, as he remarks, a close resemblance to those which now cover Greenland and Spitzbergen.—*Verhandl. Nat. Ges. Basel*, 1875–76, p. 136.

5. *The Geology of New Hampshire.* C. H. HITCHCOCK, State Geologist, J. H. HUNTINGTON, WARREN UPHAM, and G. W. HAWES, Assistants. Part II, Stratigraphical Geology. 684 pp. Royal 8vo, with many maps, plates, and sections. Concord, 1877. —A notice of this Report is deferred to another number.

6. *Lithology of the Adirondacks.*—Professor A. R. LEEDS has described, in the American Chemist for March, rocks from the Adirondacks collected by him in Essex County and mostly in the

valley and township of Keene. He adopts for the rocks, which Hunt showed to consist of feldspar identical with or near Labradorite along with hypersthene or a related augitic or hornblendic mineral (and more or less of magnetite or menaccanite), the name norite, and uses the terms hypersthenic norite, hornblendic norite, pyroxenic norite, for varieties. He gives the specific gravities of forty-four varieties of norites, which vary from 2·67 to 3·459, the proportion of the feldspar to the amphibolic species and menacanite determining it. The labradorite, from the norite forming the mass of Mount Marcy afforded him on analysis—

SiO_2	AlO_3	FeO_3	FeO	CaO	MgO	Na_2O	K_2O	H_2O	TiO_2	
54·47	26·45	1·30	0·66	10·80	0·69	4·37	0·92	0·53	undet.	=100·19

giving the quantivalent ratio for the protoxides, sesquioxides and silica, 1·13 : 3 : 6·83. Another analysis was made of a waxy felsitic variety, from the same place, which afforded very nearly the same result.

Professor Leeds gives also an analysis of a doleryte from the region, and others of the pyroxenic portion of the Mount Marcy norite. He also gives the characters afforded by thin slices of some of the rocks.

7. *On a new method of determining the species of Feldspars contained in rocks*, by Dr. J. Szabó, Professor of Mineralogy and Geology in the University of Budapest, Hungary. 88 pp. 8vo; with eleven wood-cuts and five colored plates. Budapest, 1876.—Professor Szabó states, in the opening of his memoir, that his new method of determining the feldspar species is based upon the well-known papers of Bunsen entitled "Löthrohrversuche" and "Flammenreactionen." This method, to the elaboration of which he has devoted four years of study and experiment, is based, first, upon the accurate determination of the degree of fusibility, and, secondly, upon the degree of coloration of the flame, observed under certain conditions, from which the amounts of sodium and potassium present are estimated. For the detailed description of the methods employed in the different experiments reference must be made to the paper itself. The main points are as follows: The only articles of apparatus needed are: an ordinary Bunsen lamp; a fine platinum wire fastened in a short piece of glass tube and having a small loop on the free end; and a support with an arm, adjustable at any height, to hold this glass tube. The small fragment of mineral of the size of a mustard seed, supported on the loop in the wire, is brought slowly into the flame of the Bunsen lamp at a height of five millimeters, and allowed to remain there one minute, and the amount of coloration due to sodium, or potassium (observed with cobalt glass), is noted. After removal from the flame the extent of fusion and character of the fused mass are observed. The same assay is then introduced a second time into the point of fusion of the Bunsen flame, the lamp now having its chimney on, and the same points noted as before. Finally the same piece of feldspar is moistened with distilled water and put into powdered gypsum, and thus covered it is introduced into the

hottest part of the flame and allowed to remain two minutes; the alkalies, now converted into sulphates, color the flame more distinctly than before, and this effect is duly noted.

Professor Szabó gives a general scale of fusibility containing eight degrees from quartz (0) to antimonite (7), and a special scale of six grades for the different feldspar species; he distinguishes the character of the fused products in the case of the feldspars according as a clear, milky or blebby glass, or a gray, white or blebby enamel, is obtained; he also gives large colored plates exhibiting the intensity of color, yellow and violet, corresponding, as found by experiment, to certain percentage amounts of sodium and potassium respectively. By means of these he is able to determine, within certain limits, the amount of the alkalies present in a given feldspar, and thus to determine the species.

This method doubtless requires considerable skill in manipulation, and also extended experience in the application of the delicate tests described. The end aimed at, however, is so important a one—especially in view of the tendency now prevalent to confound all the triclinic feldspars under the general term "*plagioclase*"—that it is worthy of much time and labor, and Professor Szabó deserves the thanks of lithologists for the care and minuteness with which he has worked out his results. E. S. D.

8. *Brief notices of some newly described minerals.*— *Venerite* occurs as a greenish earthy-looking "clay-ore" in irregular layers in the schists connected with the magnetite of Jones Mine near Springfield, Berks County, Pennsylvania. The purer portions have a pea-green or apple-green color when moist, becoming greenish-white on drying, when the mass falls to powder. This powder is seen under the microscope to consist of minute, transparent shining scales mixed with a little quartz and magnetite. An analysis made by Mr. G. W. Hawes, upon material purified by careful washing, gave:—SiO_2 28·93, $\dot{A}lO_3$ 13·81, $\dot{F}eO_3$ 5·04, FeO 0·27, CuO 16·55, MgO 17·47, H_2O 12·08, insoluble sand 6·22 = 100·37. After deducting the insoluble matter the composition becomes:—SiO_2 30·73, $\dot{A}lO_3$ 14·67, $\dot{F}eO_3$ 5·35, FeO 0·29, CuO 17·58, MgO 18·55, H_2O 12·83 = 100. The quantivalent ratio for $R : \dot{R} : Si : H = 3 : 4 : 6 : 4$, "which puts the mineral, if it be a homogeneous substance (as its microscopic character would indicate) among the chlorites." (Dr. T. Sterry Hunt, in a pamphlet entitled "Description of a Double Muffle Furnace by Professor B. Silliman, and A new ore of Copper and its metallurgy, by Dr. T. Sterry Hunt; Philadelphia, Dec. 30th, 1876.)

Uranocircite occurs in quartzy veins in the granite of Falkenstein, Saxon Voigtland; it has long gone by the name of autunite which it closely resembles. Specific gravity 3·49–3·56 (autunite 3·05–3·19). Optically biaxial; apparent angle of axes about 15°–20°. An analysis by Winkler gave: BaO 14·57, UO_3 56·86, P_2O_5 15·06, H_2O 13·99 = 99·88, which corresponds to the formula $BaU_2P_2O_{12}+8H_2O$ or $2(UO_2)_3P_2O_8+Ba_3P_2O_8+24nq$. (Dr. A. Weisbach, *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1877.

Sphærocobaltite occurs in spheroidal forms with roselite, at Schneeberg, Saxony. Structure coarsely radiated; the spherical surface under the microscope is found to be made up of minute rombohedral crystals; color peach-red; hardness = 4; specific gravity = 4·02–4·13. B.B. becomes black on ignition in closed tube. Dissolves with effervescence in warm hydrochloric acid. On analysis gave Winkler CoO 58·86, CaO 1·80, FeO_3 3·41, CO_2 34·65, H_2O 1·22 = 99·94, or, deducting the hydrated iron oxide CoO, 64·25, CO_2 35·75 = 100. This corresponds to the formula $CoCO_3$, which requires : CoO 63·06, CO_2 36·94 = 100. (Weisbach, l. c.)

Dysanalyte. Found in cubical crystals in granular limestone of Vogtsburg in the Kaiserstuhl; these crystals have long gone by the name of "perofskite." Specific gravity = 4·13. An analysis gave Knop: Cb_2O_5 22·73, TiO_2 40·57, FeO 5·70, MnO 0·42, CeO 5·58, CaO 19·36, MgO tr., Na_2O 3·50, K_2O tr., F tr., AlO_3 tr., SiO_2 2·31 = 100·17. This agrees closely with the formula $6RTiO_3 + RPb_2O_6$, when R = Fe, Ce, Ca, Na_2, etc. The mineral is named *dysanalyte*, in consequence of the difficulties met with in its analysis. (Knop, *Zeitschrift für Krystallographie*, i, 284, 1877.) E. S. D.

III. Botany and Zoology.

1. *Rapid Growth.*—A. W. Bennett says, of a plant of *Vallisneria spiralis:* The first flower-bud made its appearance in my aquarium this year on July 1st, the pedicel being at 3 P. M. apparently about 1·5 inch long. On the 3rd, at 4 P. M., the base of the bud just touched the surface of the water, and the pedicel was about 7 inches long. At 1 P. M. on the 7th (an interval of ninety-three hours), it had reached the astonishing length of 43 inches. The bud was then still closed, and the flower-stalk quite straight, i. e., not showing yet any tendency to coil. At 10 A. M. on the 9th the length was 45·5 inches, the flower being then open, and the lower half of the flower-stalk so strongly undulating that it was almost impossible to straighten it. At 11 A. M. on the 10th it had reached its ultimate length of 48 inches, the undulation of the lower portion being more strongly marked.

2. *Evolutionary Law as illustrated by Abnormal Growth in an Apple Tree.*—Mr. Thomas Meehan exhibited some branches of a "Smoke-house" apple tree, which had the cluster of flowers at the end of a young shoot, flowering after the leaves and growth had matured, instead of blooming in spurs early in spring, and simultaneously with the expansion of the leaves, as in ordinary cases. There were numerous instances of the normal and abnormal growths on the same tree, the abnormal ones flowering about six weeks after the normal ones, but both classes maturing the fruit at about the same time in the fall.

The point he wished particularly to draw attention to was that when there was a change in one important character, there was often change in others making a complete set of characters which need nothing but permanence to be regarded as specific. For

instance, the fruit from these terminal clusters was as unlike the normal "Smoke-house" as it was possible to be. The fruit stems were very long and slender, and the fruit flattened—what pomologists term oblate. It might further be noted that this change was not a change by gradual modification through seminal agency; but a leap, and from a tree that had always produced flowers in the normal way. There was apparently no more reason why the law, whatever it may be, that operated on this one tree might not under some circumstances operate on all the trees in the orchard, or on other wild trees in native places of growth, or on the individuals of a whole district, as well as on a single tree. It was such illustrations as these which made the doctrine of evolution in some form an absolute certainty.—*Proc. Acad. Nat. Sci. Philad.*, 1877, p. 132.

3. *Remarks on the Yellow Ant.*—Professor LEIDY remarked that recently while seeking certain animals beneath stones in the woods near Philadelphia, he had had the opportunity of observing the Yellow Ant, *Formica flava*, in possession of large numbers of other insects. This fact, in itself common enough, in one respect, was new and of special interest to him, and may be so to others. In one instance a comparatively small colony of the Yellow Ants had three different insects in their possession, consisting of a species of *Aphis*, a *Coccus*, and the larva of an insect, probably Coleopterous. The Aphides were kept in two separate herds, and these were separated from a herd of Cocci. The larva was in the midst of one of the former herds. In a larger colony of the Yellow Ants, there was a herd of Aphides which occupied the under part of one margin of the stone and was almost ten inches long by three-fourths of an inch in breadth. The same colony also possessed a separate herd of Cocci, closely crowded and occupying almost a square inch of space. In both colonies the *Aphis* and the *Coccus* were the same. The *Aphis* is pale yellow with white tubercles on the dorsal surface of the abdominal segments. The *Coccus* is of a dark-red hue. Both Aphides and Cocci, with few exceptions, adhered to the under surface of the stones, and were not attached to roots. They appeared to be carefully attended by the ants, which surrounded them. The larva alluded to was almost six millimeters long, was covered on the back with a thick white cotton-like secretion. It was also carefully attended by the ants, which were frequently observed to stroke it with their antennæ. The Aphides and Cocci were all in good condition, but without visible means of subsistence excepting the neighboring grass roots partially extending into the earth beneath the stones, to which it is probable they were at times transferred by their masters.—*Proc. Acad. Nat. Sci.*, 1877, p. 145.

4. *Sexual Dimorphism in Butterflies.*—Mr. S. H. Scudder, in an article on sexual dimorphism in Butterflies—to which special kind of dimorphism he applies the term *Antigeny*—states that it is not the male but the female that departs from the normal type of coloring of the group to which the species belongs; while it is

the male that shows divergences from the type in structural characters. These structural divergences in Butterflies appear in the wings and the legs, and sometimes in the antennæ. Mr. Scudder knows of no example in which the male alone diverges from the general plan of coloration belonging to the group.—*Proc. Amer. Acad.*, 1877.

IV. Miscellaneous Scientific Intelligence.

1. *Narrative of the North Polar Expedition, U. S. Ship Polaris, Captain Charles Francis Hall commanding.* Edited under the direction of the Hon. G. M. Robeson, Secretary of the Navy, by Rear Admiral C. H. Davis, U. S. N., United States Naval Observatory. 696 pp. large 8vo. Government Printing Office, Washington. 1876–77.—The melancholy interest which attaches to the death of the enthusiastic explorer, Hall, just as he was seemingly about to realize his life-long hopes, is increased by the reflection that the distinguished officer, to whom was entrusted the preparation of this narrative, was himself called away by death while his task was almost complete. The final chapters were consigned by him to the editorial care of Professor Nourse of the National Observatory. This volume is what its title declares—a narrative of the Polar Expedition from its inception in 1870 until the "Frolic" brings the survivors of the party to Washington, on the 5th of June, 1873, after experiences which must ever be considered memorable, even among the almost incredible trials and heroisms of Arctic exploration. The closing chapters of the narrative recite the cruises of the Juniata and Tigress for the rescue of the Polaris and her crew, the examination of the icefloe, and the Buddington Parties, with the Report of the Board of Enquiry. The volume also contains a translation of the report made to the Royal Geographical Society of Paris, April 21, 1875, by M. V. A. Malte Brun, awarding the Roquette gold medal to the memory of Hall in consideration of eminent services in Arctic exploration, which medal was sent to the family of the unfortunate explorer; the instructions of the National Academy of Sciences; the correspondence between the British Admiralty and the U. S. Navy Department in relation to the stores left by the Polaris Expedition on the west coast of Greenland; the Journals of Mr. H. C. Chester and Captain Geo. E. Tyson while on boat journeys, June and July, 1872; and lastly a list of the Journals used in the preparation of the Narrative of the Polaris Expedition.

The scientific results of the expedition have been worked up by Dr. Bessels, under the supervision of the Smithsonian Institution, in three volumes, the publication of which may be shortly expected.

This narrative is illustrated by thirty-eight full page wood engravings from original sketches by Mr. Emil Schumann and Dr. Emil Bessels, painted in oil by Mr. J. H. Morgan and photographed on wood by Mr. Smilie. There are also eighteen tail pieces from original sketches, two photolithographs, a steel por-

trait of Captain Hall, and a steel engraved frontispiece of the Polaris.

It is a pleasure to know also that Professor Nourse is now engaged in preparing for publication Captain Hall's Journals during his second expedition, 1864-69, in obedience to a resolution introduced into the U. S. Senate, February 6, 1877, by Mr. Sargent. B. S.

2. *The American Meteorologist*, JOHN H. TICE, Editor. In monthly numbers of 32 pages, 8vo. Saint Louis, Missouri.—The second volume of this Journal, consisting of six monthly numbers, commenced with January of the current year. The author holds peculiar views with regard to meteorological and other phenomena, and their causes, and presents them in his Monthly. Facts are, in his opinion, in "irrepressible conflict," as he expresses it, with ordinary physical theories.

3. *The American Journal of Pure and Applied Mathematics.*—Under this title, a much needed addition to the scientific journals of the country, will soon be made, under the auspices of the Johns Hopkins University. The editors announced are: J. J. SYLVESTER, BENJAMIN PEIRCE, SIMON NEWCOMB, H. A. ROWLAND, and WM. E. STORY, the first, "Professor of Mathematics in the University, bearing the title of Editor-in-Chief," and the last being "Associate-Editor-in-Charge." Four numbers in quarto, will for the present be issued annually, making a volume each year of 384 pages. The price is five dollars a volume. The first number will appear in January, 1878. Subscriptions and contributions should be addressed to WILLIAM E. STORY, Johns Hopkins University, Baltimore, Maryland.

4. *Publications of the Cincinnati Observatory.*—Two numbers —2 and 3—have recently been issued in octavo. No. 2, eighteen pages, contains Micrometrical Measurements of 176 double and triple stars, observed with the 11-inch reflector of the Observatory by O. M. Mitchell; Cincinnati, 1876; and No. 3, thirty-four pages, bears the title, Micrometrical Measurements of 166 double and triple stars, during the years 1875–76, under the superintendence of Ormond Stone, A.M., Director, Cincinnati, 1877.

5. *Two New Meteoric Irons.* (Letter to the Editors.)—I have had lately sent to me two new meteoric irons, one from Casey County, Kentucky, and the other from Dalton, Whitfield County, Georgia. Descriptions and analyses of these will be published shortly. J. LAWRENCE SMITH.

6. *Table of Logarithms.* — M. GAUTHIER VILLARS has published in Paris a volume of logarithms, containing tables for all numbers from 0 to 434,000,000,000 with twelve decimals, by M. Namur, Secretary of the Ecole Moyenne of Thuin (on the Sambre, Belgium). This wonderful volume, selling at three francs, has been printed by order of the Royal Academy of Sciences of Belgium.—*Nature*, July 5.

7. *Tenth Annual Report of the Trustees of the Peabody Museum of American Archæology and Ethnology.* Presented

to the President and Fellows of Harvard College, June, 1877. Vol. II, No. 1, 168 pp. 8vo. Cambridge, 1877.—A paper, by Dr. C. C. ABBOTT, describes the occurrence of what appear to be flint chippings in undisturbed gravel deposits, only partially stratified, of the Delaware River valley, near Trenton, New Jersey. The stone is a hard or indurated argillite, somewhat fusible before the blowpipe; but in one case, flint. Bowlders eight or ten feet in diameter occur over the surface. Mr. Abbott regards the material as of Glacial origin, and the relics, as those of man of the Glacial era. This paper is followed by another, by Professor N. S. SHALER, on the same relics and deposits, which states that he accompanied Dr. Abbott over the region, and obtained from the beds two of the supposed relics, and concludes with the remark that "if these remains are really those of men, they prove the existence of interglacial man on this part of our shore."

This Report contains also papers on the exploration of Ash Cave in Benton, Hocking County, Ohio, and on explorations of mounds in Southeastern Ohio, by Professor E. B. ANDREWS; on the exploration of a mound in Lee County, Va., by LUCIEN CARR, Assistant Curator in the Museum; and on the Art of War and Mode of Warfare of the Ancient Mexicans, by AD. F. BANDELIER.

Professor Andrews describes instruments, beads, and other ornaments of copper, from the mounds examined by him. One of the mounds (W. Connett's in Dover, Athens County, Ohio) is spoken of as "of great scientific value, because by it we prove that the mound-builders sometimes practised cremation."

In the paper by Mr. Carr, on the Virginia Mound, it is stated that among the relics obtained from it, Mr. J. A. Allen identified the bones of the *Caribou*, and remarked that "this is farther south than bones of the Caribou have hitherto been found."

8. *Kinetic Theories of Gravitation;* by WILLIAM B. TAYLOR. From the Smithsonian Report for 1876. Washington. Government Printing Office. 1877. pp. 78, 8vo.—This is a valuable historical *résumé* of the various attempts that have been made, by the most eminent philosophers, to account for the phenomena of gravitative attraction, from the time of Newton to the present day. The sketch is concluded by a vigorous criticism of the leading theories, in which the author, passing over "the consideration of the *statical* method of explaining gravitation by pressure," finds that "*kinetic* systems are essentially of two classes, the hypotheses of emissions or corpuscles, and the hypotheses of fluid undulations," and proceeds to show "that neither form of either hypothesis can satisfy the two Newtonian conditions of a scientific theory—*verity* and *sufficiency*." A. W. W.

Vacher's Primer of Chemistry. Lindsay & Blakiston, Philadelphia.

OBITUARY.

TIMOTHY ABBOTT CONRAD.—Dr. CONRAD died on the ninth of August, at the residence of his brother-in-law, Mr. T. Abbott, Trenton, New Jersey. He was son of the late Solomon Conrad, of the University of Pennsylvania, and was born in 1803.

His scientific labors began early in life and were continued up to the present year. They were devoted especially to the study and description of recent shells and the fossil shells of the Tertiary and Cretaceous formations of the United States; and in the Tertiary species they exceed in importance those of any other American Paleontologist excepting Mr. Meek. As early as 1832 he published the first number of an illustrated work on the "Fossil shells of the Tertiary formation," which, however, was never completed; and in 1831 began his "American Marine Conchology," which he carried to 72 pages and 17 plates. Later his papers were published from time to time in this Journal, and in the Publications of the Academy of Sciences of Philadelphia; the first communication to this Journal appearing in 1833, and the last in February, 1877. Memoirs by him are also to be found in the reports of various surveying expeditions. Between 1835 and 1841 he issued thirteen numbers of a "Monography of the Family Unionidæ," with many colored plates. In part of his publications he was his own lithographer. During the years 1838 to 1841, Professor Conrad had charge of the Paleontological department of the Geological Survey of New York, and his Annual Reports for those years and the Journal of the Philadelphia Academy for 1842, contain descriptions of many of the species discovered—the larger part of all that were known previous to the labors of Professor James Hall, into whose hands this department fell in 1843. Some of his general geological conclusions are presented in his "Notes on American Geology," published in this Journal for 1839 (vol. xxxv, 237), in which he advocates the doctrine (which Agassiz first suggested) that the grander divisions of geological time, or abrupt transitions in life, were determined by cold intervals in the course of the earth's progress, and he points out the great fact that the Mississippi depression, as it is often called, was a consequence of the elevation of the Appalachians on the east, and of the Rocky Mountain area, late in geological time, on the west. On the first of these points he remarks that "the theory of periodical refrigeration alone can explain the sudden extinction of whole races of animals and vegetables."

Professor Conrad took a most important part in laying the paleontological foundations of American Geology—a work shared largely also by Lea and Lyell as regards the Tertiary, by Morton for the Cretaceous, and, still more largely, by Hall for the Paleozoic species, and carried forward later by other able paleontologists.

Robert Were Fox, F.R.S., died on the 25th of July, in the eighty-eighth year of his age, "having spent his long life in acts of usefulness and deeds of the purest Christian benevolence." His experiments on the temperatures of deep mines proving an increase of depth downward, on the electro-magnetic properties of mineral veins, and his construction of the first dipping needle, are among the important scientific works that have given his name a world-wide reputation. "To his latest days, in the retirement of his beautiful home, he delighted to surround himself with intellectual friends," and watched with unfailing interest the progress of scientific discovery.

APPENDIX.

ART. XXXIII.—*Notice of some new Vertebrate Fossils;* by O. C. MARSH.

THE specimens described in the present article are all from the Rocky Mountain region, and include Mammals, Birds, Reptiles, and Fishes. Among the Mammals are two Miocene Edentates, the first detected in this country, and a third species of this group from the lower Pliocene. Another Mammal of much interest is a Rhinoceros from the Eocene, the oldest known member of the family. A number of new genera are introduced, some of which have an important bearing on the genealogy of Tertiary Mammals. Among the other vertebrates is a new genus of Crocodilians from the horizon of the Wealden, and a species of *Crocodilus* from the Pliocene.

Moropus distans, gen. et sp. nov.

This genus of Edentates is based mainly upon the bones of the feet, which have been found in several individuals. These remains are quite different from the feet bones of any of the American Edentates, recent or fossil; but indicate affinities with the extinct *Ancylotherium*, from the Tertiary of Europe, which is supposed to be related to the African Ant-bear (*Orycteropus*). The specimens here described belong to a distinct family, the *Moropodidæ*.

In the type specimen of the present species, only the hind feet appear to be represented. One of the most characteristic bones is a coössified first and second phalanx. The articulation for the metatarsal is nearly in a horizontal plane, and situated on the proximal end of the upper surface of the base. It is somewhat heart-shaped in outline with the apex rounded and about equally concave in both directions, or slightly less so transversely. This articulation occupies nearly half the length of the first phalanx which is thoroughly coössified with the second. The line of junction between the bones can, however, be traced easily, and is strongly marked on the under surface by a pit or foramen entering obliquely upwards and forwards. Except near this line of junction, the surface of the

bone is rather smooth. The under surface, below the articulation, is flattened. The second phalanx is less than half the length of the first, and its surface is roughened, as if by abnormal growth of bone over the surface. The length of the first phalanx is 43^{mm}; the longitudinal diameter of the metacarpal articulation 18^{mm}; its transverse diameter 23^{mm}. The least transverse diameter of the bone is 21^{mm}: its vertical diameter at the middle is 20^{mm}. The second phalanx is broken in this specimen, its distal articular face being absent.

Associated with the above specimen, is a short bone evidently a median phalanx, with both articular surfaces well preserved and in form corresponding to each other. Proximally there are two grooves separated by an intermediate ridge, and distally two pulley-shaped ridges with a deep groove between. The length of the shaft of this bone is 23^{mm}; its transverse diameter is 21^{mm} proximally, and 17^{mm} distally. Near the center of the terminal pulleys is a deep pit on each side. The greatest vertical diameter of the bone is 32^{mm}. This bone resembles the penultimate phalanx of the middle finger of *Priodontes*, but is somewhat shorter and thinner.

These and other less characteristic remains indicate an animal somewhat larger than a tapir. They were found in the Miocene of Oregon by the Yale Expedition of 1873.

Moropus senex, sp. nov.

A second larger species of the same genus is indicated by a few remains, among which is the characteristic bone formed of the united phalanges. The proximal phalanx is considerably larger than the one above described. Its length is 52^{mm}. The proximal articulation is oblique, and does not occupy more than one-third the upper surface of the bone. The median phalanx is well preserved, and measures 25^{mm} in length. It is not united with the first phalanx in a line with the axis of that bone, but is inclined about 15° toward the sole of the foot. Its distal articulation is composed of two not very prominent pulley-shaped surfaces with a groove between.

Moropus elatus, sp. nov.

The largest species of this genus, now known, is represented at present by a number of bones of the posterior extremities, mainly from the feet. The peculiar duplex bone already mentioned is among them, and affords means for comparing the different species.

The proximal phalanx here measures about 90^{mm} in length, and the medial one 40^{mm}. The articulation for the metatarsal is more nearly vertical than in either of the Miocene species. Its median vertical diameter is 30^{mm}; and transverse diameter

42mm. The least vertical diameter of the phalanx is 28mm; transverse diameter 31mm. The second phalanx has a transverse diameter of 32mm, and a vertical diameter of 49mm, measured across the curve of the terminal pulley. The least vertical diameter is 38mm.

Associated with this bone is a well preserved first metatarsal, measuring 135mm in length. Its minimum transverse diameter is 25mm. The proximal surface is subtriangular, with the external side of the triangle curved outward, and the other shorter sides somewhat curved inward. The external three-fourths of the surface is transverse, and occupied by a nearly flat articular surface, which rises along a vertical ridge near the inner margin of the face. Beyond this ridge, the upper part of the surface shows marks of articulation with another bone. The inner face of the bone is somewhat concave proximally; it then presents a low broad elevation, and is flattened distally. The shaft of the bone is rounded throughout. The distal articulation is hemispherical above, but presents two shallow grooves below, which are carried around so far as to become nearly horizontal. The greatest proximal diameter is 50mm, and the greatest distal diameter 44mm.

The proximal face of the fifth metatarsal is oblique, triangular in outline, convex vertically, and through the greater part of its tranverse extent. Its greatest vertical extent is 65mm, and greatest horizontal diameter the same. The vertical diameter of the shaft of this bone is 40mm, and its transverse diameter 38mm. The calcaneum measures 108mm from its posterior end to the vertical face for articulation with the astragalus. The vertical diameter of the shaft is 53mm, and the transverse diameter 41mm.

These remains are from the Lower Pliocene of Nebraska, and indicate an animal about as large as a Rhinoceros.

Amynodon, gen. nov.

The present genus is based upon a nearly perfect skull, and various other remains which belonged to the oldest representative of the Rhinoceros family yet discovered. These specimens are from the Uinta or *Diplacodon* beds, of the Upper Eocene, and about the horizon of the Paris basin. The skull is intermediate in form between that of a Tapir and a Rhinoceros, but the molar teeth are entirely of the latter type. The premolars are all unlike the molars, and the canines above and below are very large. The incisors are small, and the inner one in each jaw is lost in the present adult animal. The lower canines are placed nearly horizontal, and taken in connection with the rest of the anterior dentition, they prove conclusively that the large lower teeth, usually regarded as incisors

in *Acerotherium* and many other members of the Rhinoceros family, are really canines.

The nasals in this genus are smooth, and evidently were without horns. There were four toes in front and three behind. The type species is *Amynodon advenus* Marsh, which was provisionally referred to the genus *Diceratherium* when first described.

Tapiravus rarus, gen. et sp. nov.

The paucity of Tapiroid remains in the Miocene and Pliocene lake basins of Western America is a singular fact, probably due in part to temperature, and in part to the nature of the surrounding country. The few specimens found have been referred to *Lophiodon*, a Lower Eocene genus. Various remains from these formations on the Atlantic coast and in the West show, however, that they are quite distinct from *Lophiodon* and the existing Tapir, and represent an intermediate genus, which may be called *Tapiravus*. The type species is *T. validus* Marsh, (*Lophiodon validus*) from the Miocene of New Jersey. This genus may readily be distinguished from *Lophiodon* or *Hyrachyus*, by the last upper premolar, which is similar to the adjoining molars.

A second species of this genus occurs in the Lower Pliocene east of the Rocky Mountains, and remains were collected there by the writer in 1873. The most characteristic specimen obtained was an upper molar tooth which indicated an animal considerably smaller than the living Tapir. The crown of this molar was 15^{mm} in antero-posterior diameter, and 17^{mm} in transverse diameter. It is peculiar in having the antero-exterior angle very obtuse, and less prominent than the outer cusps.

Bison ferox, sp. nov.

This genus has not hitherto been found in the Tertiary of this country, although not uncommon in later deposits. The Museum of Yale College contains two well preserved horn-cores from the later Tertiary, one of which was found by the writer in the lower Pliocene of Nebraska. This is quite as low as the genus has been found in the Old World. This specimen indicates an animal much larger than the existing Bison, and having very powerful horns. The specimen preserved was over 500^{mm} in length, when complete. The radius of the inner curve measures about 400^{mm}. The largest end has a diameter of 125^{mm}, and the smaller, at a distance of 300^{mm}, measures 77^{mm}.

A second larger species, with more curved horns, is indicated by a nearly perfect horn-core from the lower Pliocene of Kansas. This species, which may be called *Bison Alleni*, in honor of Dr. J. A. Allen, of Cambridge, also had very large

horns. The type specimen has its greatest and least diameters near the base, 140^{mm} and 110^{mm}. At a distance of 300^{mm} further toward the end, the diameters are 100^{mm} and 90^{mm}. The radius of the inner curvature, except for the last 150^{mm} of the length, was 350^{mm}.

The discovery of these two lower Pliocene species of Bison, suggests the probability that this form is a New World type, although it has generally been credited to the other hemisphere.

Allomys nitens, gen. et sp. nov.

Among the Upper Miocene mammals, a peculiar genus is found, which is probably related to the flying squirrels, but the teeth are somewhat like those of Ungulates. Its affinities are evidently with the Rodents, however, and it represents a distinct family, the *Allomyidæ*. The general characters of the upper molar teeth are shown in the accompanying figure,

which is six times natural size. The animals of this species are all very small, hardly larger than a rat. The extent of three molar teeth is 8^{mm}. The transverse distance between the two series is, in front, 3·8^{mm}, and posteriorly, 4·4^{mm}.

The known remains of this species are all from the Upper Miocene of Oregon.

Graculavus lentus, sp. nov.

The Cretaceous deposits of the Atlantic coast and of Kansas have hitherto alone yielded remains of Birds, but these have recently been found in beds of the same age in Texas. The most characteristic specimen obtained is the distal end of a metatarsal, which differs from the corresponding bone of the toothed birds from Kansas, and may be referred provisionally to the genus *Graculavus*, the type of which is from the Upper Cretaceous of New Jersey. This specimen shows that there were three toes of nearly equal size, and also a hallux raised above the main digits.

Transverse diameter of shaft of tarsometatarsal bone	4·2^{mm}
Vertical diameter of same	3·6
Transverse diameter across distal articular faces	10·
Vertical diameter of median distal articular face	4·8

The known remains of this species indicate a bird about as large as a small duck.

Diplosaurus felix, gen. et sp. nov.

An interesting discovery recently made in the lower Cretaceous, or Wealden beds, of Colorado, is a new genus of Crocodilians, intermediate between the old Teleosaurian type and the modern *Crocodilus*. The new genus has a head and teeth very similar to the latter, but with this the ancient biconcave vertebræ. The present type species is based upon a nearly perfect skull, and a number of vertebræ belonging with it. These pertained to an animal smaller than most existing Crocodilians.

Some of the principal measurements of this species are as follows:

Length of skull on median line	255·mm
Length of skull from quadrate to end of snout	275.
Transverse diameter of premaxillaries	46·
Transverse diameter of skull, at front of orbits	90·
Transverse diameter at ends of quadrates	122·
Transverse diameter of quadrate at end	20·

A second species of this genus is apparently the *Hyposaurus Vebbii* Cope, which may be called *Diplosaurus Vebbii*.

Crocodilus solaris, sp. nov.

No Miocene Crocodilians are known from the Western lake-basins, and none have been described from the Pliocene of the same regions. One species, however, lived in the Pliocene lake east of the Mountains, and, as an indication of climate, at least, is well worthy of record. The remains preserved indicate an animal of moderate size, well protected with deeply pitted bony plates, and probably belonging to the genus *Crocodilus*.

Measurements of some of the more important remains are the following:

Length of centrum of lumbar vertebræ	42· mm
Vertical diameter of anterior articulation	25·
Transverse diameter	30·
Vertical diameter of neural canal	11·
Vertical diameter of posterior articulation	25·
Transverse diameter	30·
Transverse diameter of dermal scute	34·

These specimens were found by the writer, in 1873, on the Niobrara River in Nebraska.

Nanosaurus agilis, gen. et sp. nov.

The most diminutive Dinosaur yet discovered is represented by various portions of a skeleton recently received from the Mesozoic deposits of the Rocky Mountains. These remains indicate an animal not larger than a cat, and yet apparently fully adult. Most of the bones are hollow, and the walls thin.

The crowns of the teeth are apparently compressed, and inserted in distinct sockets. The femur has the characteristic third trochanter, and is shorter than the tibia.

The principal dimensions of this pigmy Dinosaur are as follows:

Space occupied by five teeth in lower jaw	13· mm
Depth of jaw below last tooth	10·
Length of femur	63·
Distance from head to middle of third trochanter	25·
Length of tibia	75·
Least diameter of shaft	6·

The geological horizon of this unique fossil is probably Jurassic, but possibly in the lower part of the Dakota group, which I regard as the equivalent of the Wealden of Europe.

Nanosaurus victor, sp. nov.

Another small Dinosaur, which may be provisionally referred to the same genus, is indicated by portions of a skeleton found in the same region, and probably at or near the same horizon. These remains belonged to a reptile about twice as large as the one just described. The bones are equally hollow, and the walls very thin. The tibia is much more elongated, and slender. No teeth were found with this specimen. The length of the tibia was about 100^{mm}, and the diameter of its shaft at the middle 6^{mm}. A metatarsal bone measures 41^{mm} in length. The remains at present known indicate an animal about as large as a fox.

Apatodon mirus, gen. et sp. nov.

One of the most interesting specimens hitherto found in the Rocky Mountain region, is a portion of a lower jaw with the last molar in place. This fossil is widely different from anything yet described, and its exact affinities are doubtful. The fragment pertained to an animal about as large as a Tapir, and the general appearance of the specimen at once suggests the mammalian type. The tooth most resembles, in form and superior surface of crown, that of a typical Suilline. The structure of the tooth, however, is different, and the fangs are, in part at least, coössified with the jaw.

This specimen was found near a locality where Dinosaur bones were abundant, and it is possible it may belong with that group. The jaw, however, is very unlike any corresponding jaw of a Dinosaur, so far as now known. This tooth measures about 41^{mm} in length of crown; 20^{mm} in transverse diameter, and 8^{mm} in height. The geological horizon is Lower Cretaceous or Jurassic.

Heliobatis radians, gen. et sp. nov.

The most interesting fossil Fish hitherto found in the Tertiary of the west is a land-locked Ray, recently discovered in the Green River beds of Wyoming. The specimen is in excellent preservation, and shows the characters of the group most perfectly. It differs much from recent Rays, and resembles most nearly the genus *Cyclobatis* of Egerton, from the Mt. Lebanon deposits of Syria, which are probably in nearly the same horizon as the locality of the present specimen. The latter differs from *Cyclobatis* in having a much greater number of radiating digits, which entirely encircle the body, and suggested the generic name. There are also numerous dermal defensive tubercles, which are wanting in *Cyclobatis*.

The principal dimensions of this rare specimen are as follows:

Antero-posterior extent of rays	235·mm
Transverse diameter across scapular arch to bases of rays	75·
Total transverse diameter	220·
Transverse diameter of head	82·
Distance between scapular and pelvic arches	55·
Length of vertebræ at pelvic arch	2·6
Length of vertebræ in caudal region	2·

Yale College, August, 1877.